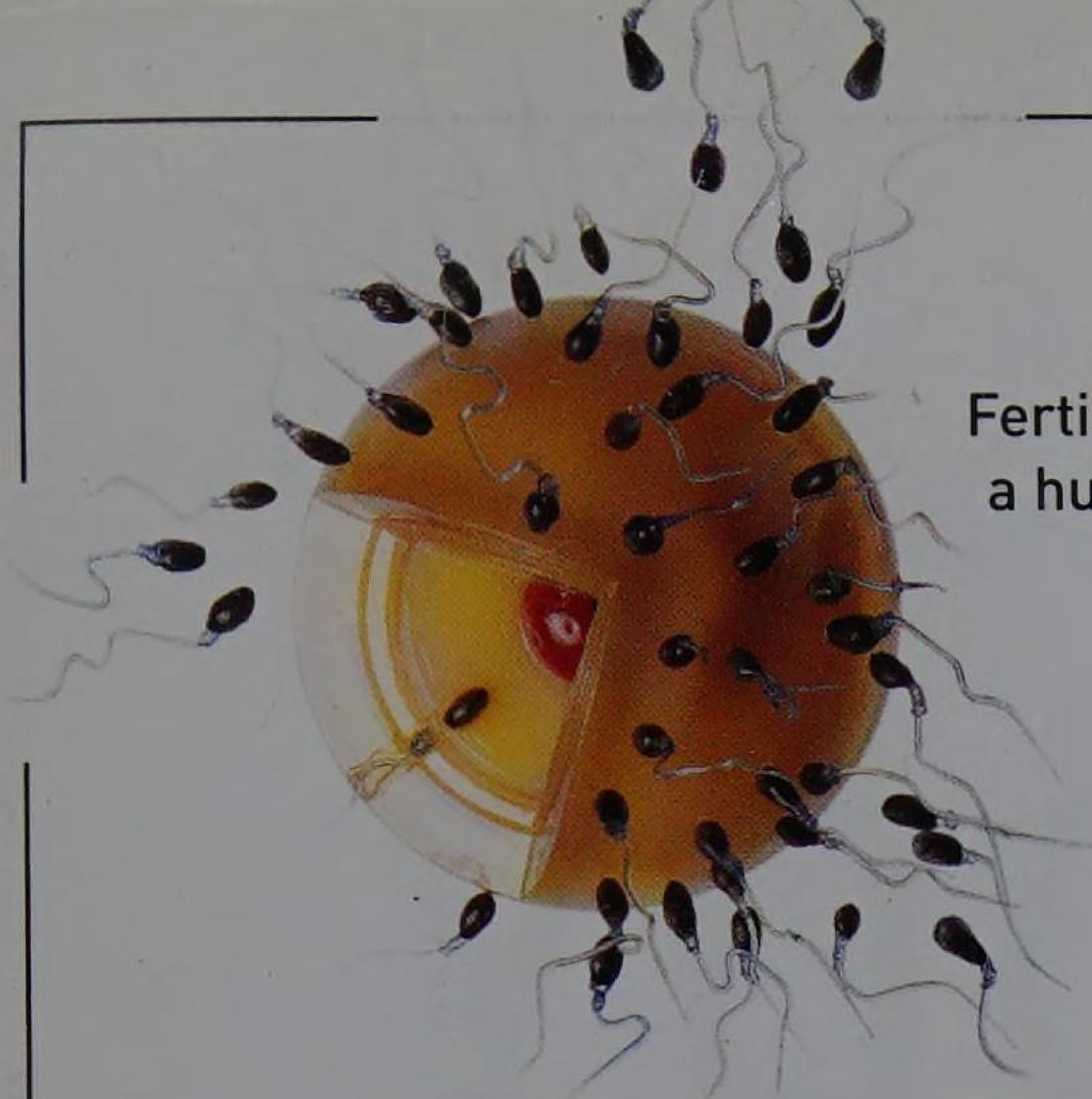
DK EYEWITNESS

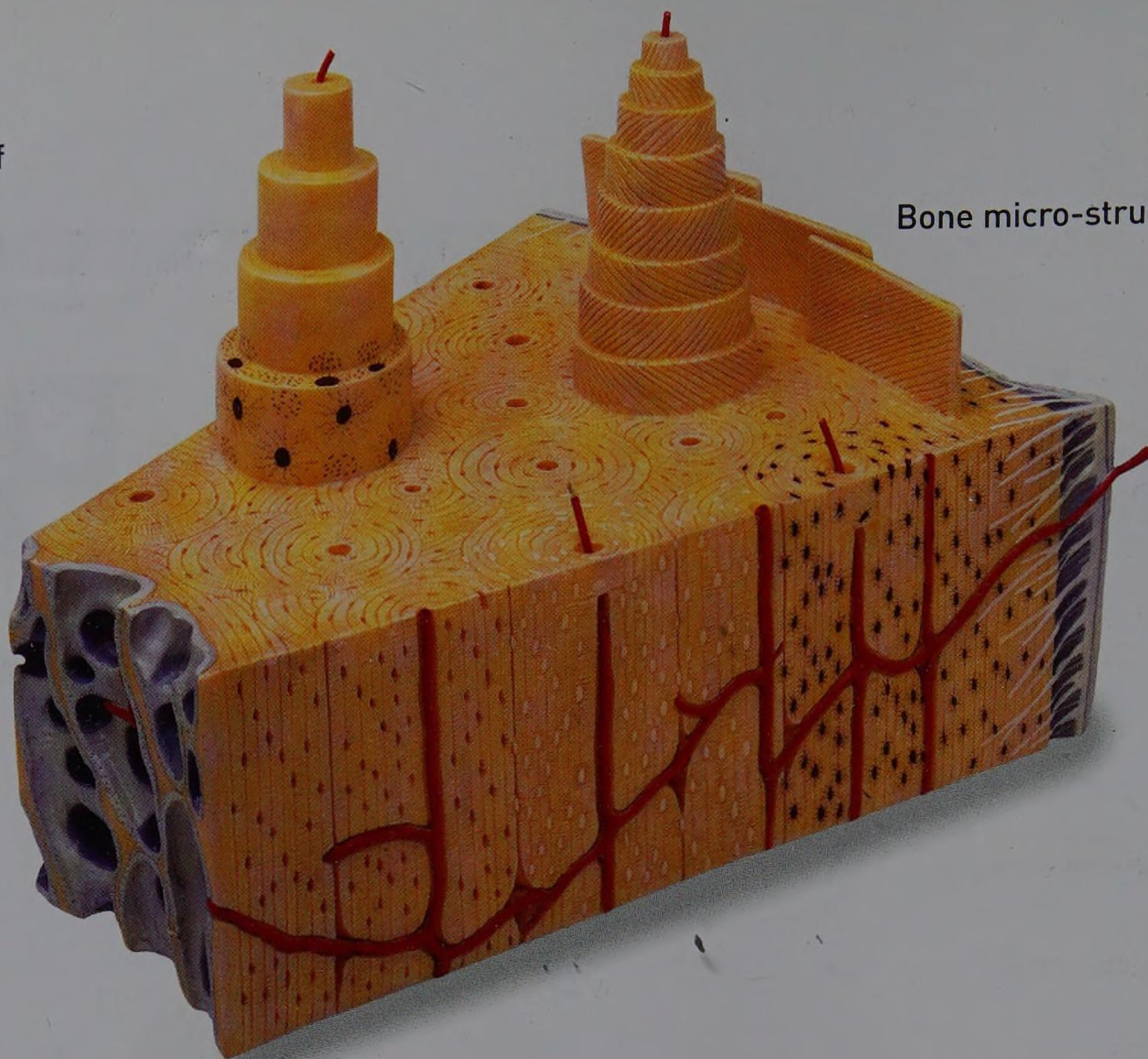
HUMAN BODY

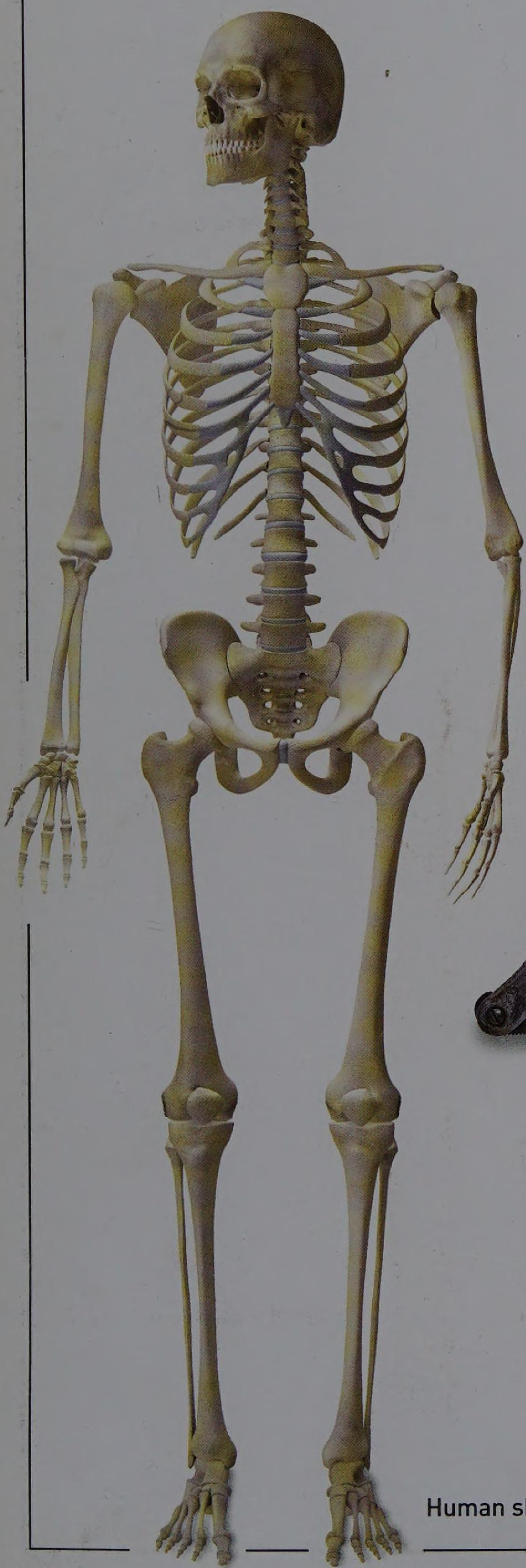
Explore how the human body works – from the smallest cells to the systems that keep us alive

EYEWITNESS

HUMAN BODY

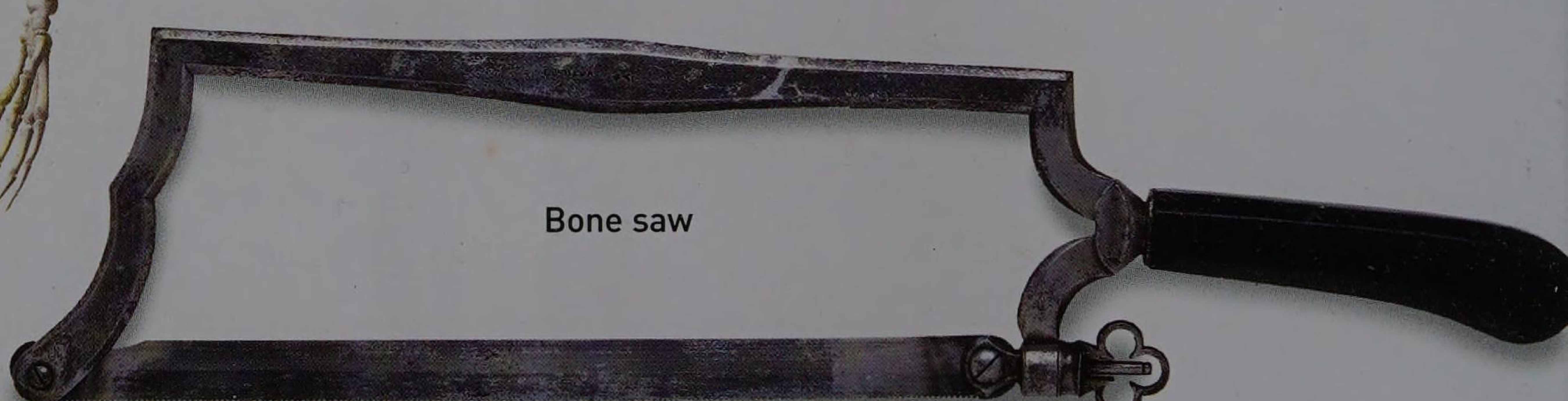

Fertilization of
a human egg

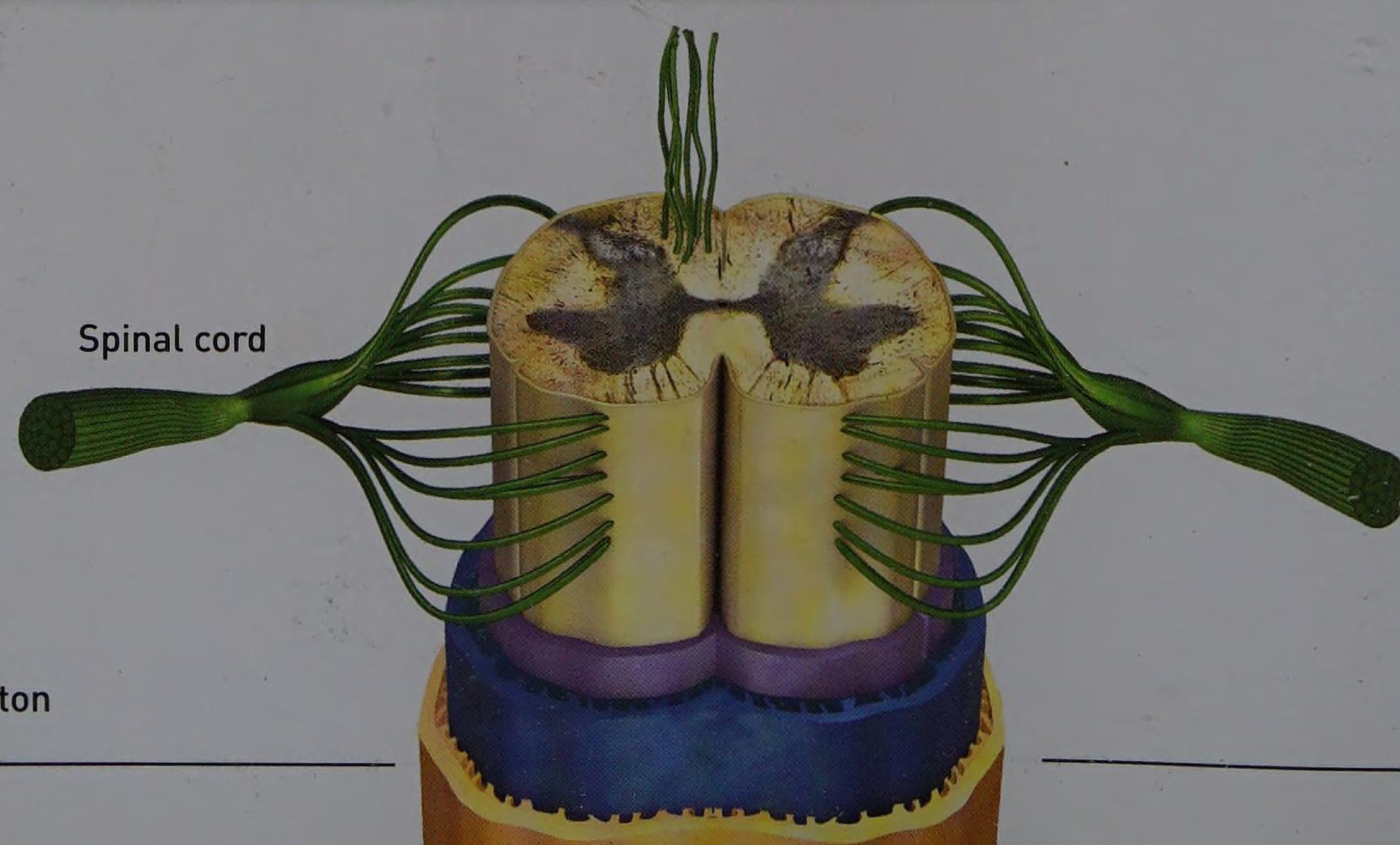

Bone micro-structure

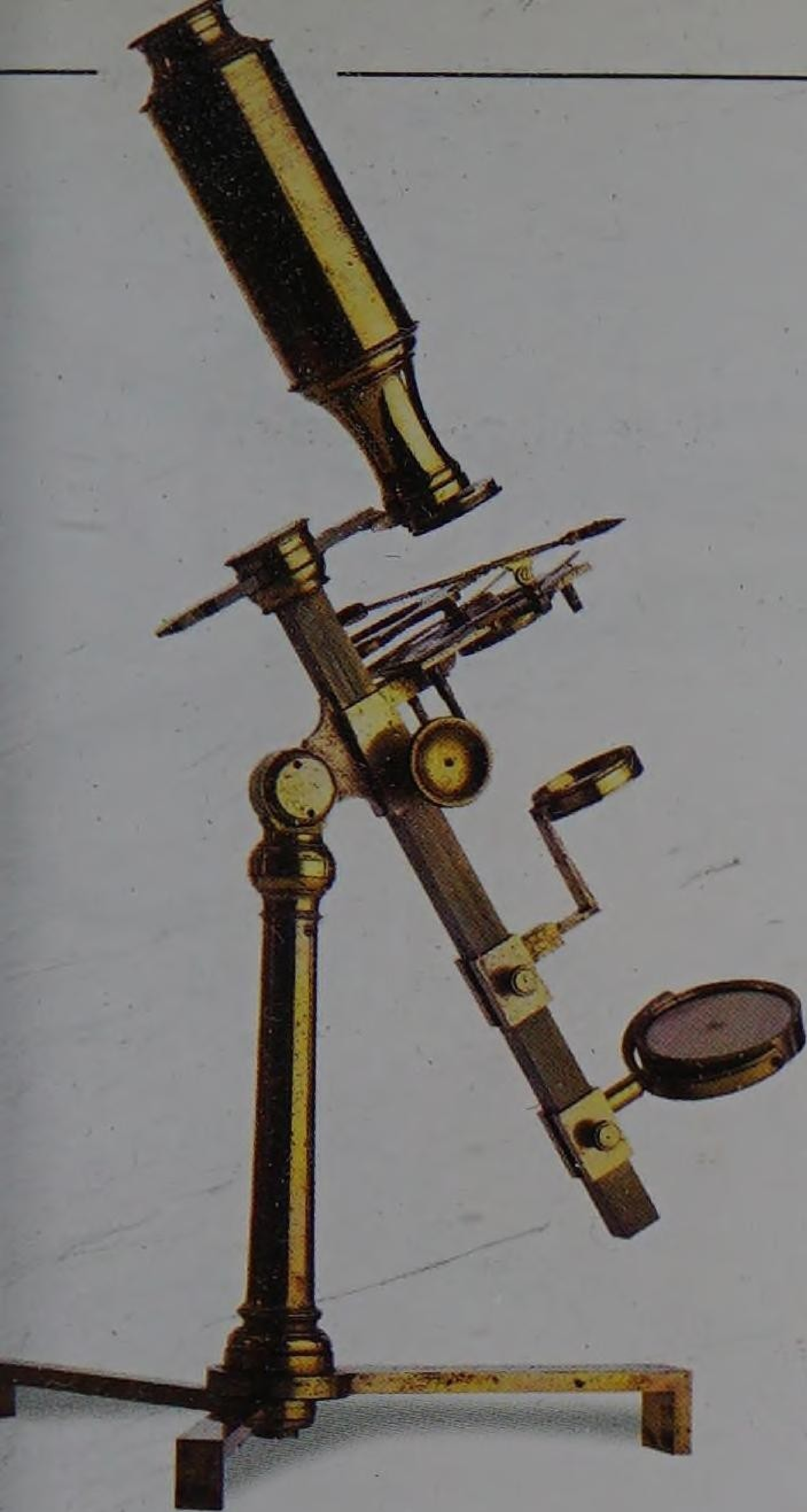

Human skeleton


Fingerprint


Red blood cells


Bone saw


Spinal cord

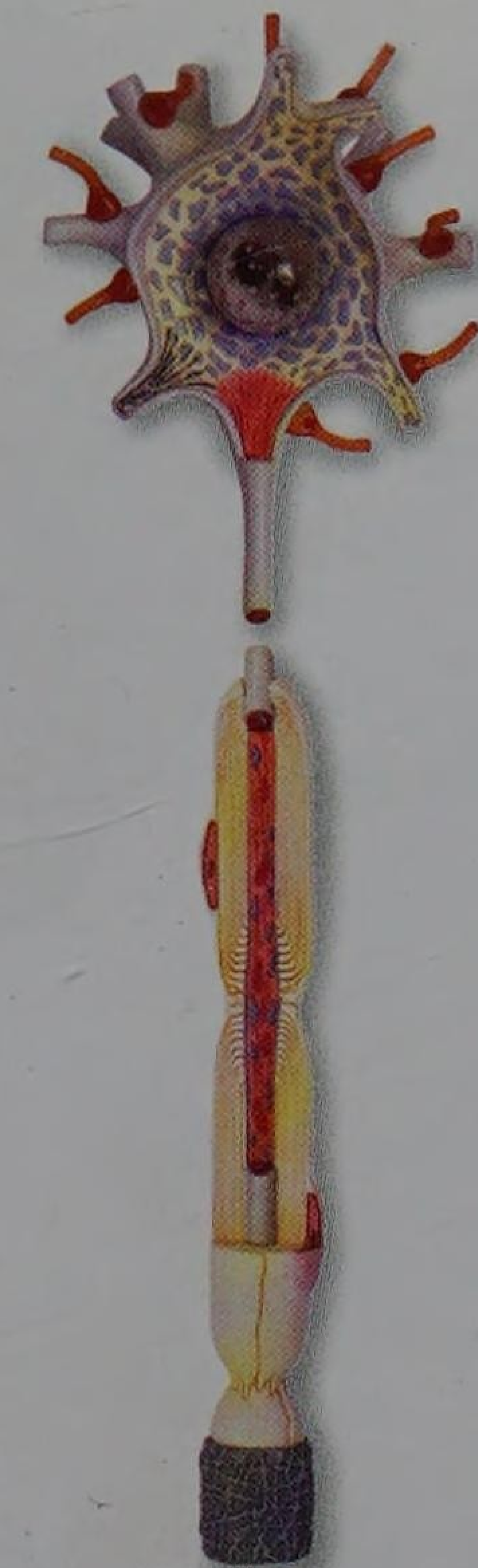


Compound microscope

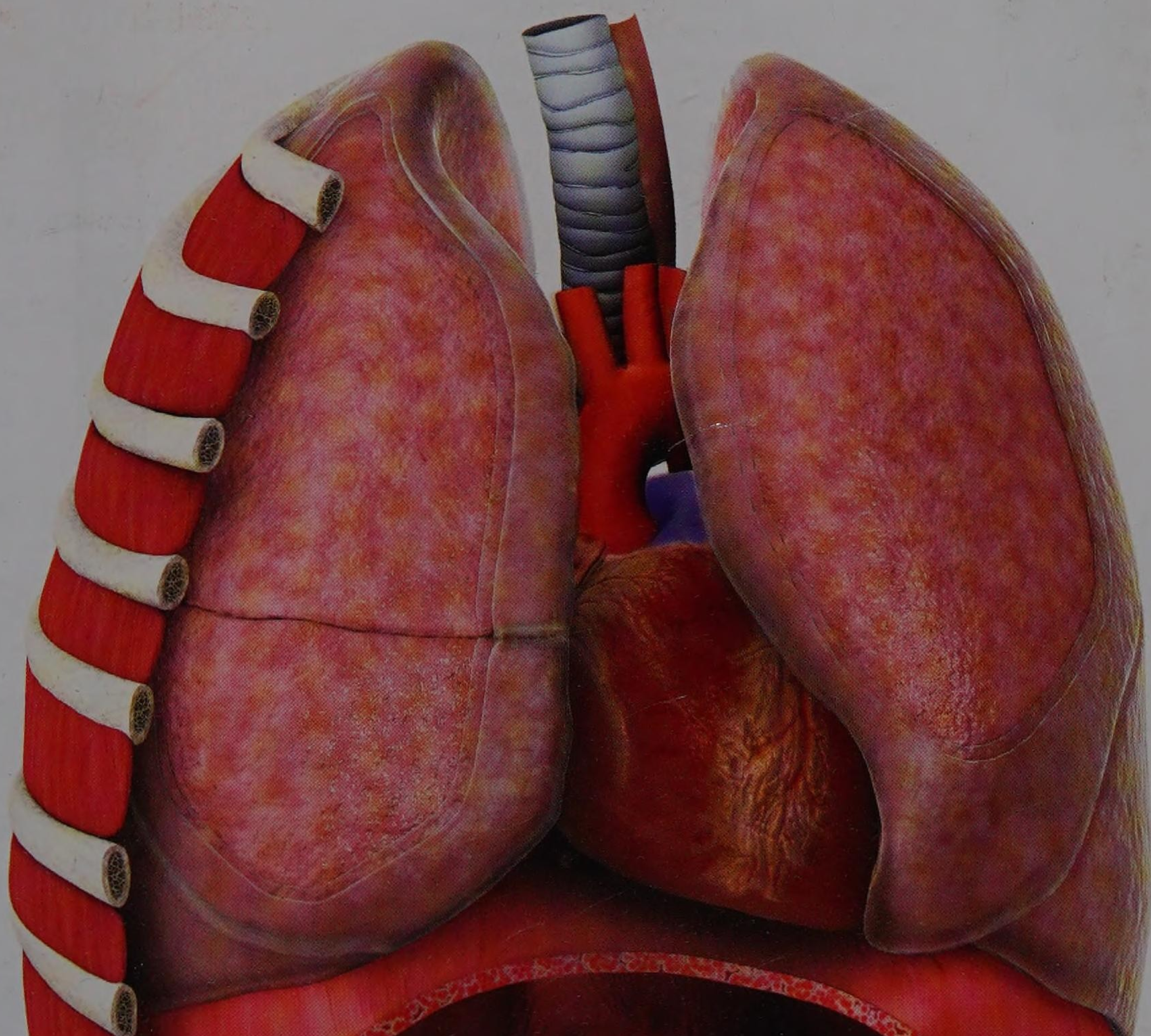
EYEWITNESS HUMAN BODY

Written by

Richard Walker



Nerve cell



Respiratory system

DK

Chromosome

19th-century clamping forceps

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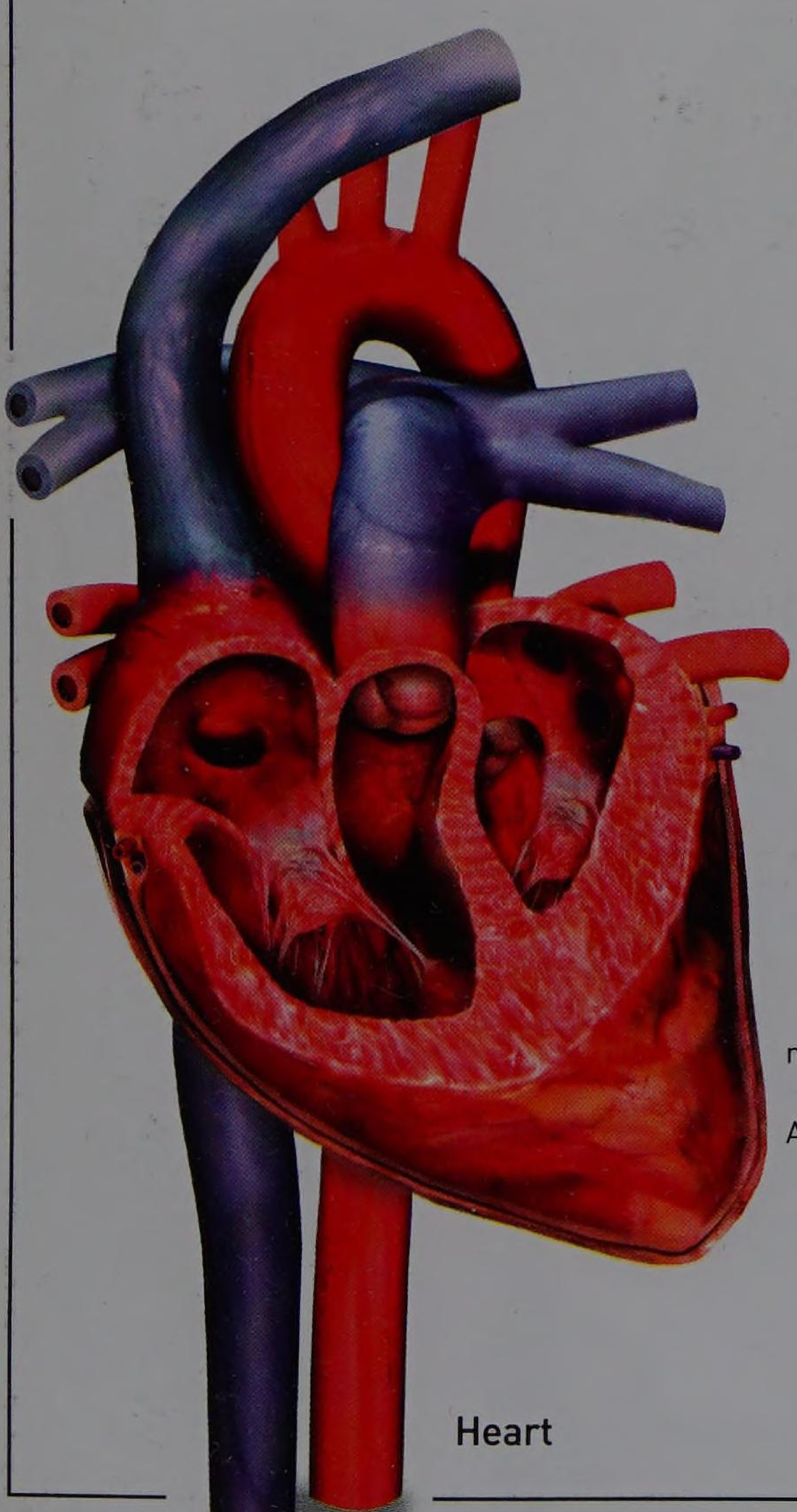
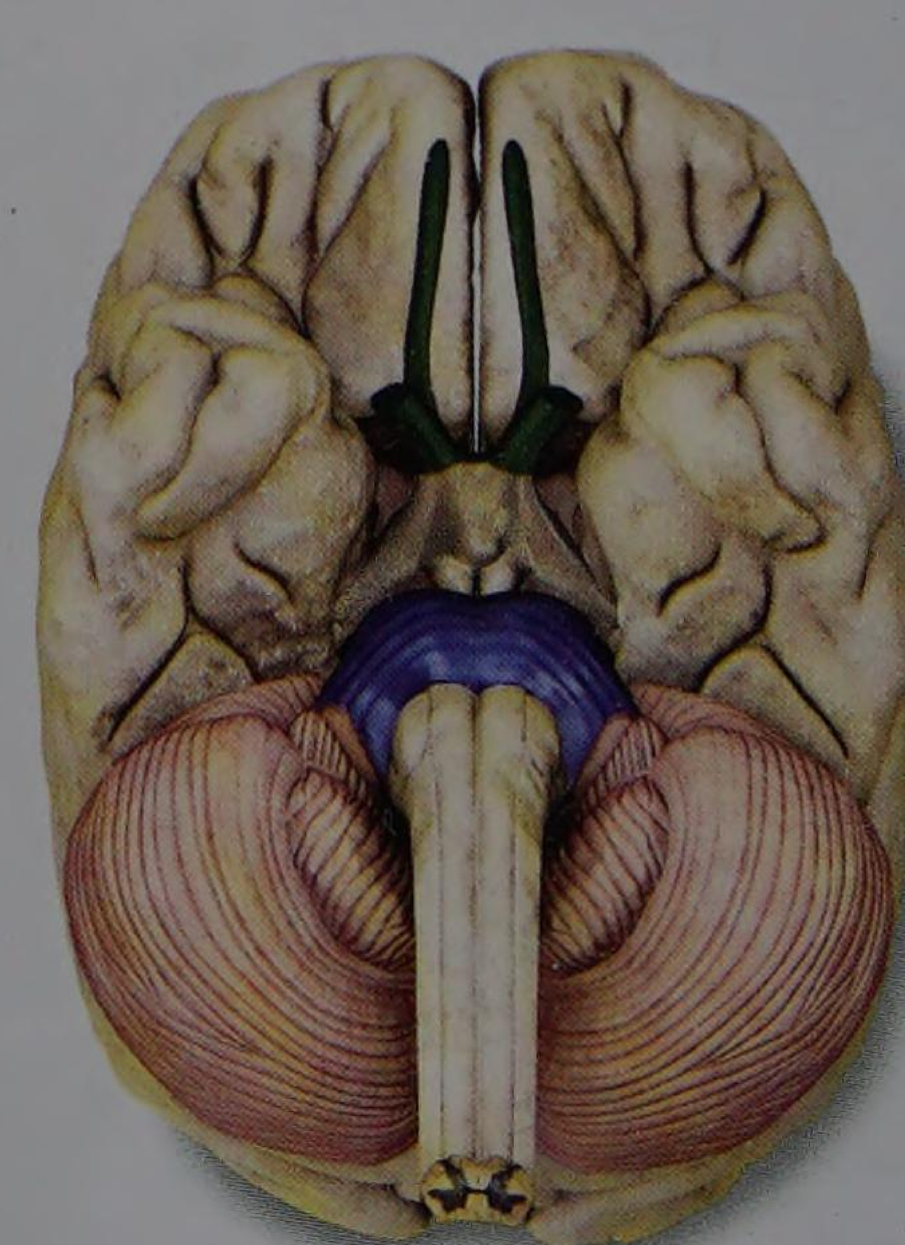
Adult teeth

Cross-section of the skin

Oxygen-rich blood | Oxygen-poor blood | Settled blood



Heart



Brain from below

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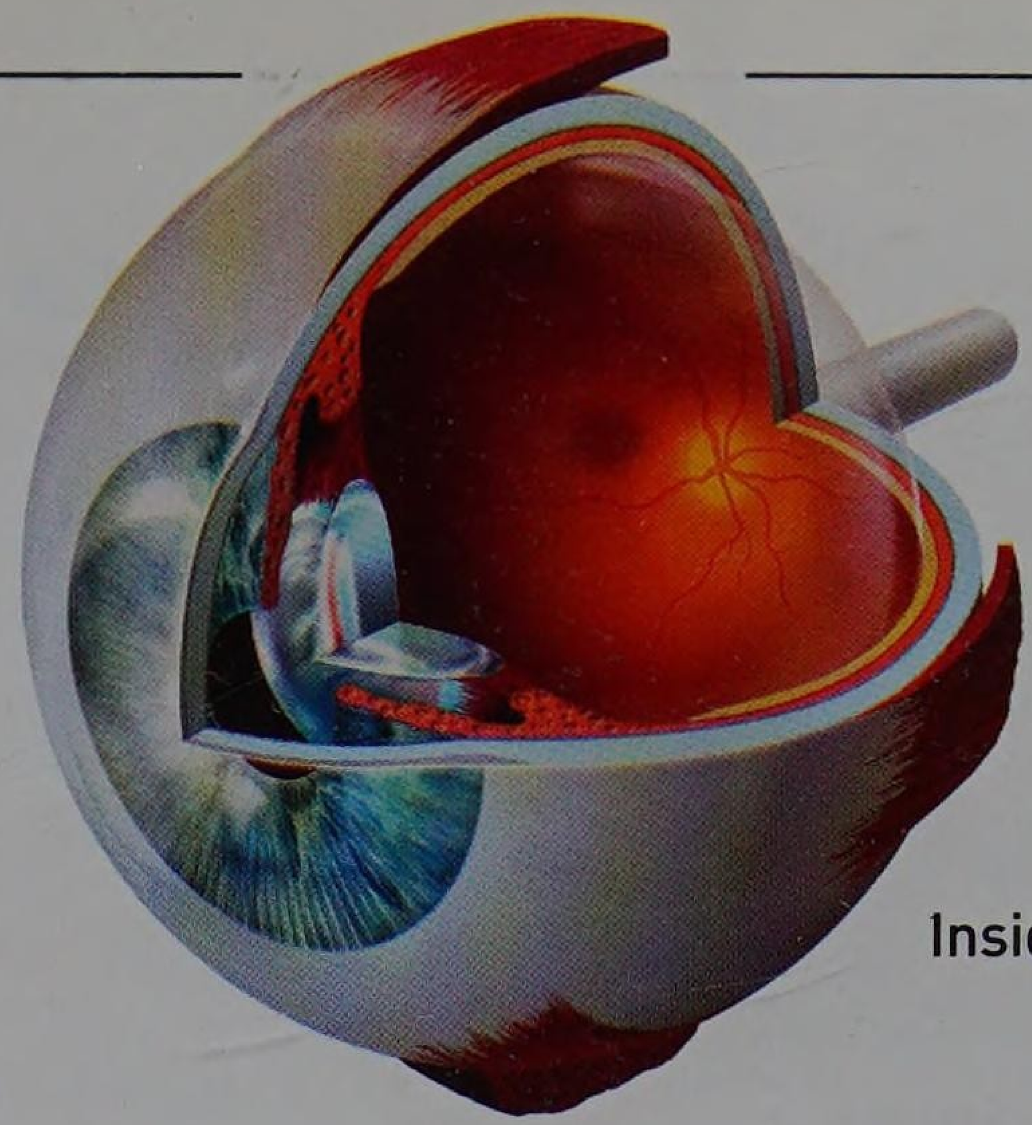
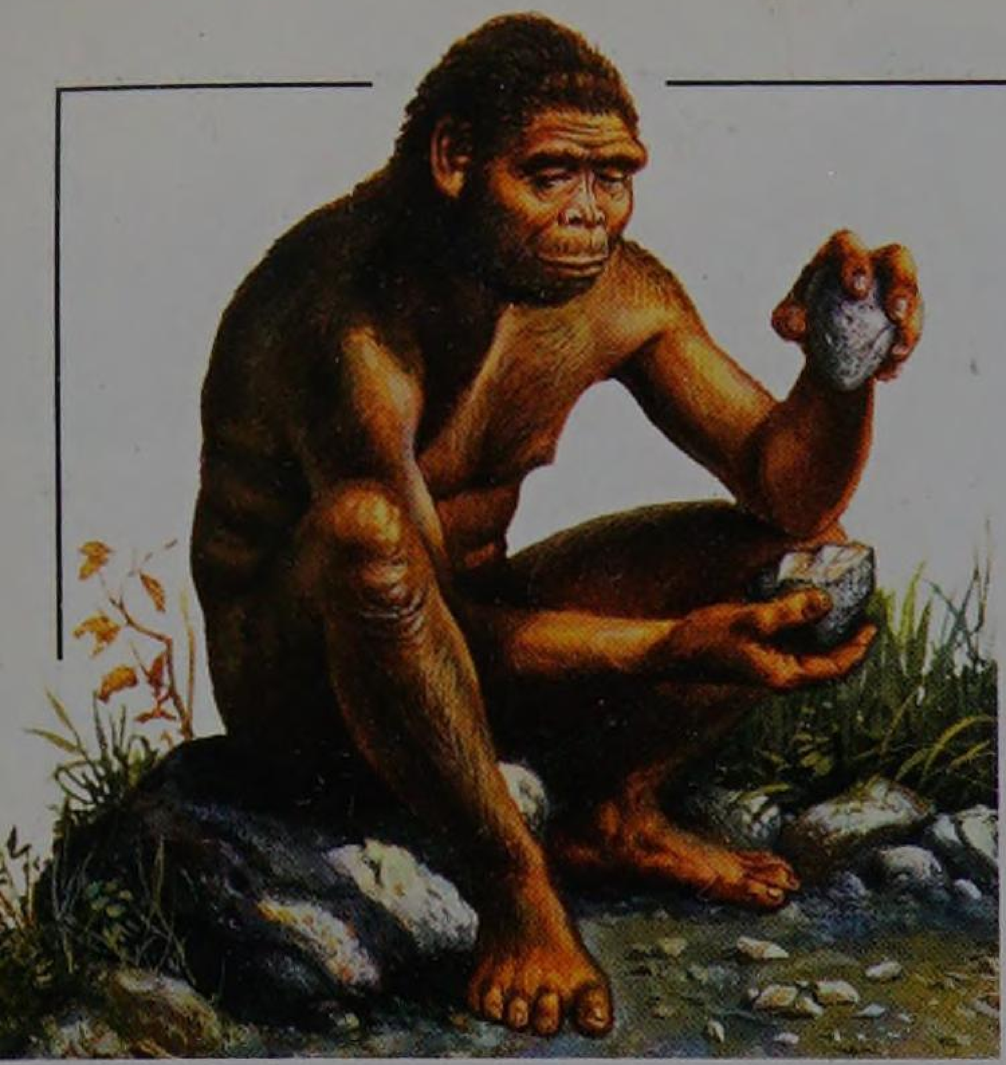
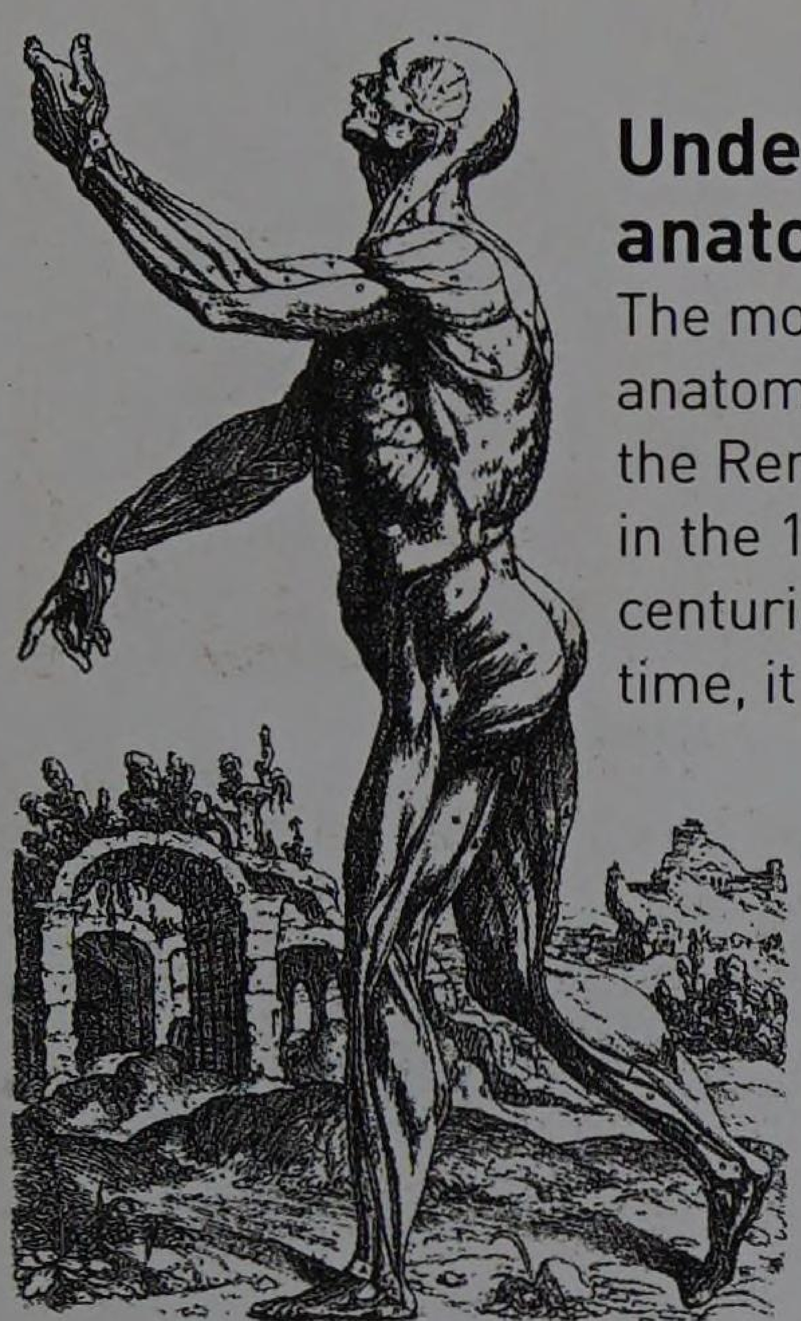

Inside the eye

The human body

We may look different from the outside, but our bodies are all constructed in the same way. The study of anatomy, which explores body structure, shows that internally we are virtually identical – apart from differences between males and females. The study of physiology, which deals with how the body works, reveals how body systems combine to keep our cells, and us, alive.

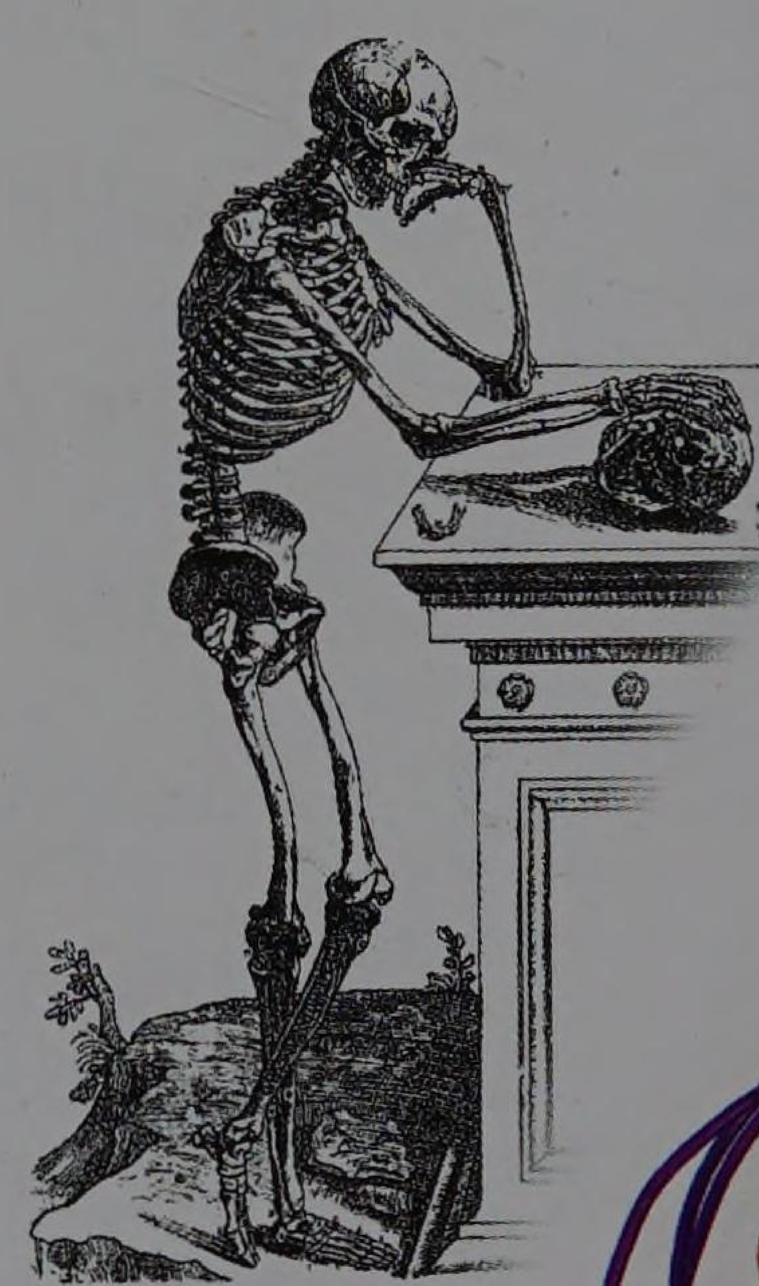


Human origins
Human beings are all related. We belong to the species *Homo sapiens*, and are descendants of the first modern humans, who lived in Africa 160,000 years ago and migrated across the globe.



Muscular system

Understanding anatomy
The modern study of anatomy dates back to the Renaissance period, in the 15th and 16th centuries. For the first time, it became legal to dissect, or cut open, a dead body in order to examine its parts in minute detail and make accurate drawings.



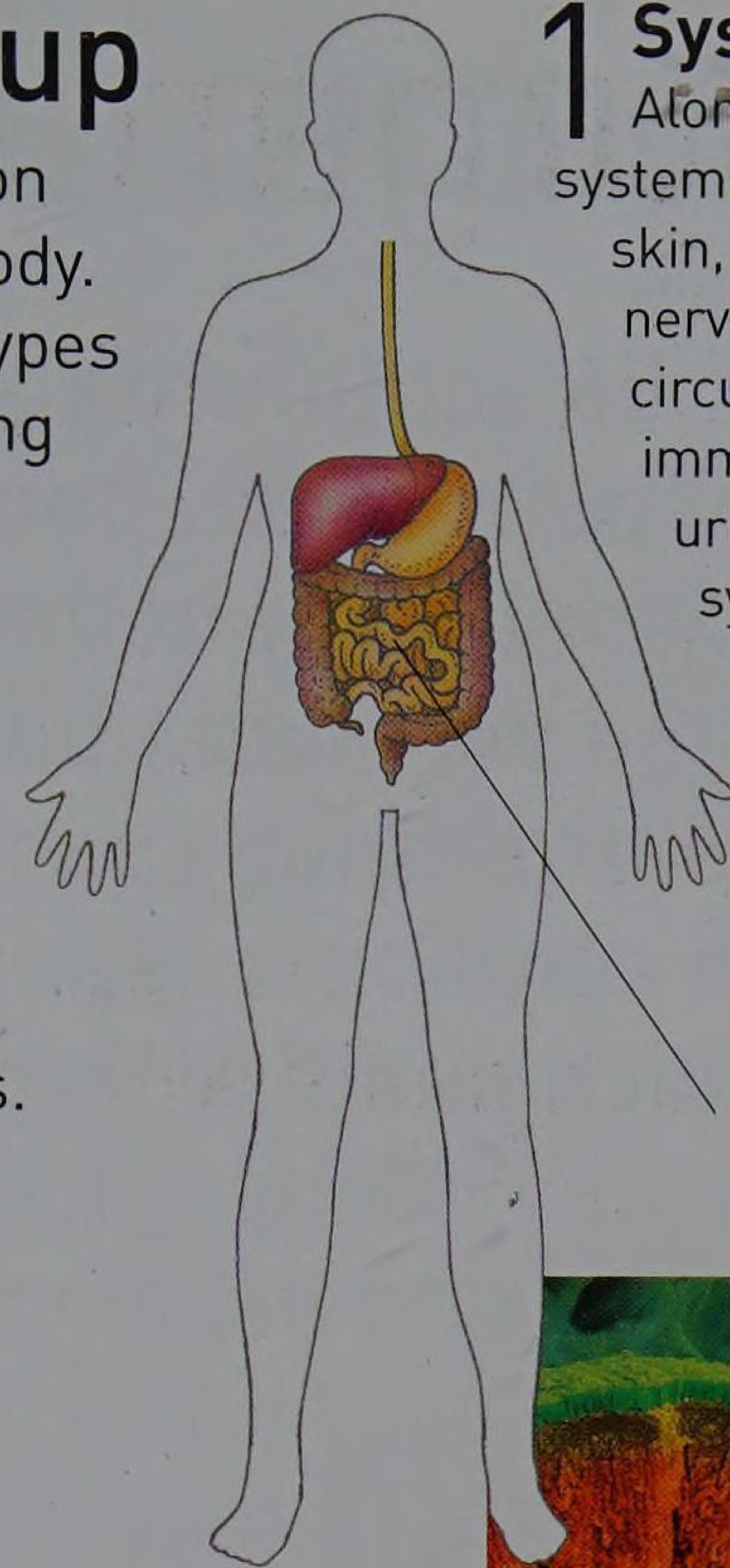
Skeletal system

The body as a building
In 1708, physiologists likened the body to a busy household – bringing in supplies (eating food), distributing essentials (the blood system), creating warmth (body chemical processes), and organizing everyone (the brain).

Working together
Our internal organs and systems work together to keep us alive. Bones, muscles, and cartilage provide support and movement. Nerves carry control signals. The heart and blood vessels deliver food everywhere, along with oxygen taken in through the lungs. The result of this cooperation is a balanced internal environment, with a constant temperature of 37°C (98.6°F). This enables cells to work at their best.

Body make-up

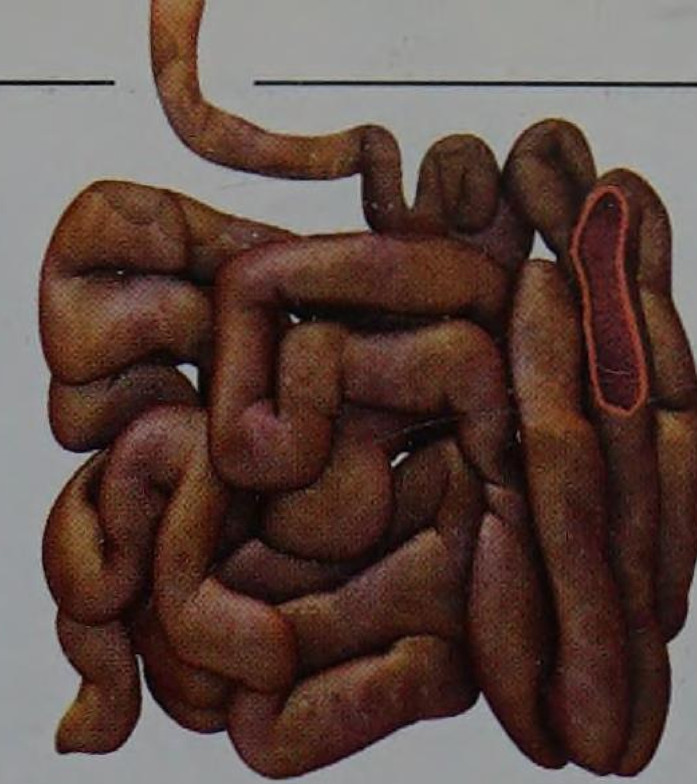
It takes around 100 trillion cells to build a human body. There are 200 different types of these microscopic living units, each of which is highly complex. Similar cells join together to make a tissue, two or more tissues form an organ, and linked organs create a system. The body has 12 systems.



Digestive system

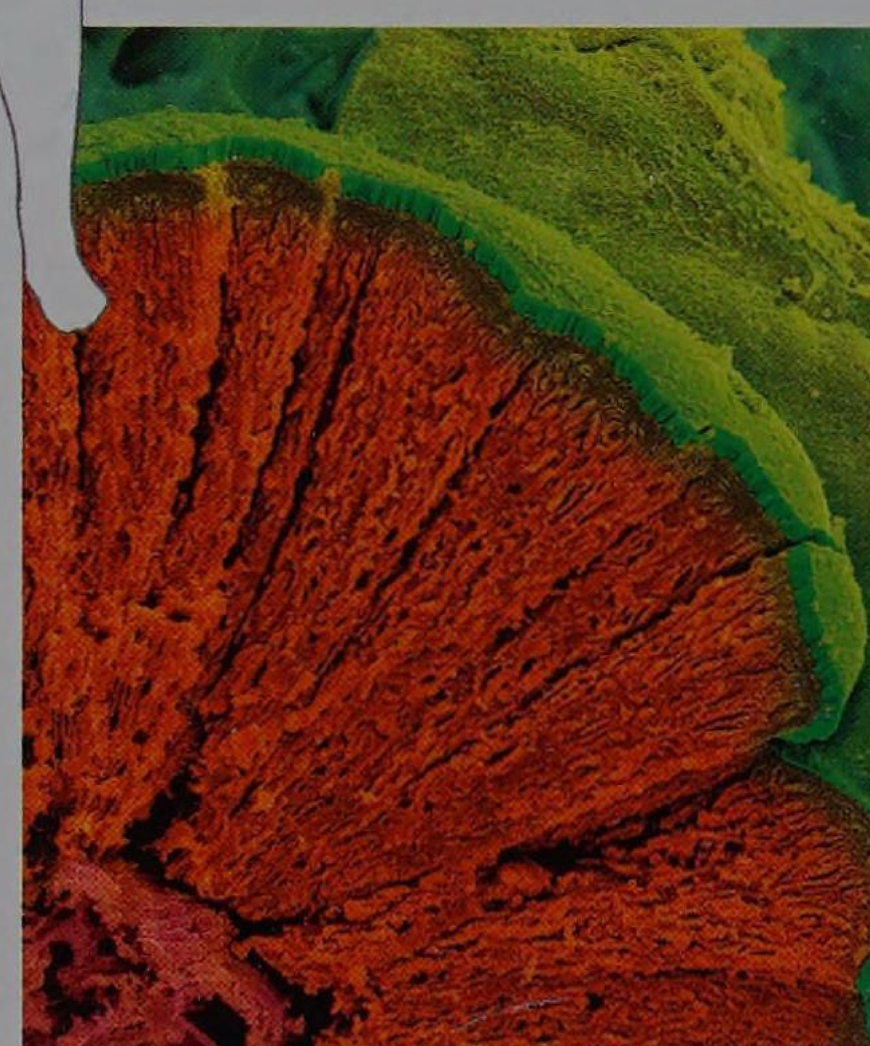
1 System

Along with the digestive system, the other 11 are the skin, skeletal, muscular, nervous, hormonal, circulatory, lymphatic, immune, respiratory, urinary, and reproductive systems. The role of the digestive system is to break down food so it can be used by body cells.



2 Organ

The small intestine is a long digestive tube. It completes the breakdown of food into simple substances, which are absorbed into the blood. Muscle tissue in the wall of the small intestine pushes food along it.



3 Tissue

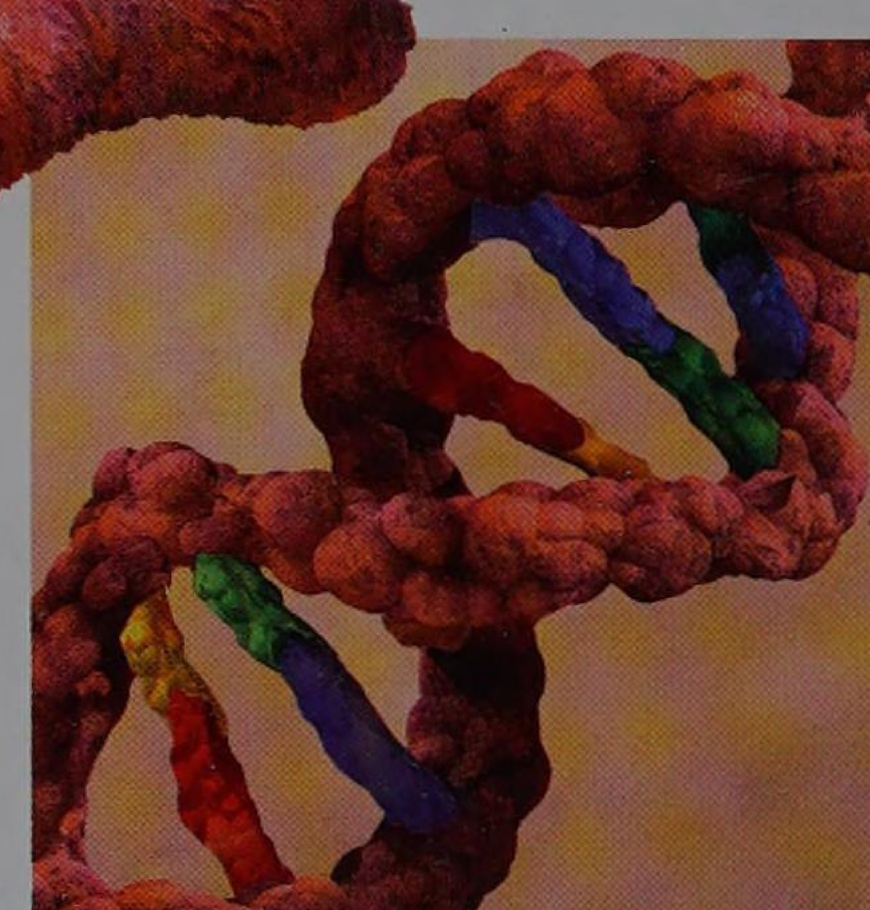
The lining of the small intestine has millions of microscopic finger-like projections called villi. This epithelial tissue provides a vast surface for absorbing food.

4 Cells

The epithelial cells covering a villus are tightly clumped together, which stops food and digestive juices leaking through to the tissues that support these cells.

5 Chromosome

Every cell has a control centre, called its nucleus, which contains 46 chromosomes. These long threads (coiled up in an X-shape, above) contain coded instructions, called genes, which are needed for building our cells, tissues, organs, and systems.



6 DNA

Each chromosome consists of deoxyribonucleic acid (DNA), a molecule. DNA's twisted strands are linked by chemicals called bases (blue, green, red, yellow). Their sequence provides a gene's coded instructions for building or controlling the body.

Myth, magic, and medicine

Prehistoric art
The Aboriginal rock art of Australia has featured X-ray figures showing the internal anatomy of humans and animals for 4,000 years.

Early humans made sculptures and cave paintings of human figures. As civilizations grew, people began to study the world around them and their own bodies more closely, but care for the sick and injured was tied up with myths, superstition, and a belief that gods or demons sent illnesses. The "father of medicine", Greek physician Hippocrates (c. 460–377 BCE) taught that diseases could be identified and treated. In the Roman world, Galen (129–c. 216 CE) set out ideas about anatomy and physiology that would last for centuries. As Rome's power declined, medical knowledge spread east to Persia, developed by physicians such as Avicenna (980–1037 CE).

Holes in the head
This 4,000-year-old skull from Jericho, in Israel, shows the results of trepanning, or drilling holes in the skull – probably to expose the brain and release evil spirits. Modern surgery uses a similar technique, called craniotomy, to release pressure in the brain caused by bleeding.

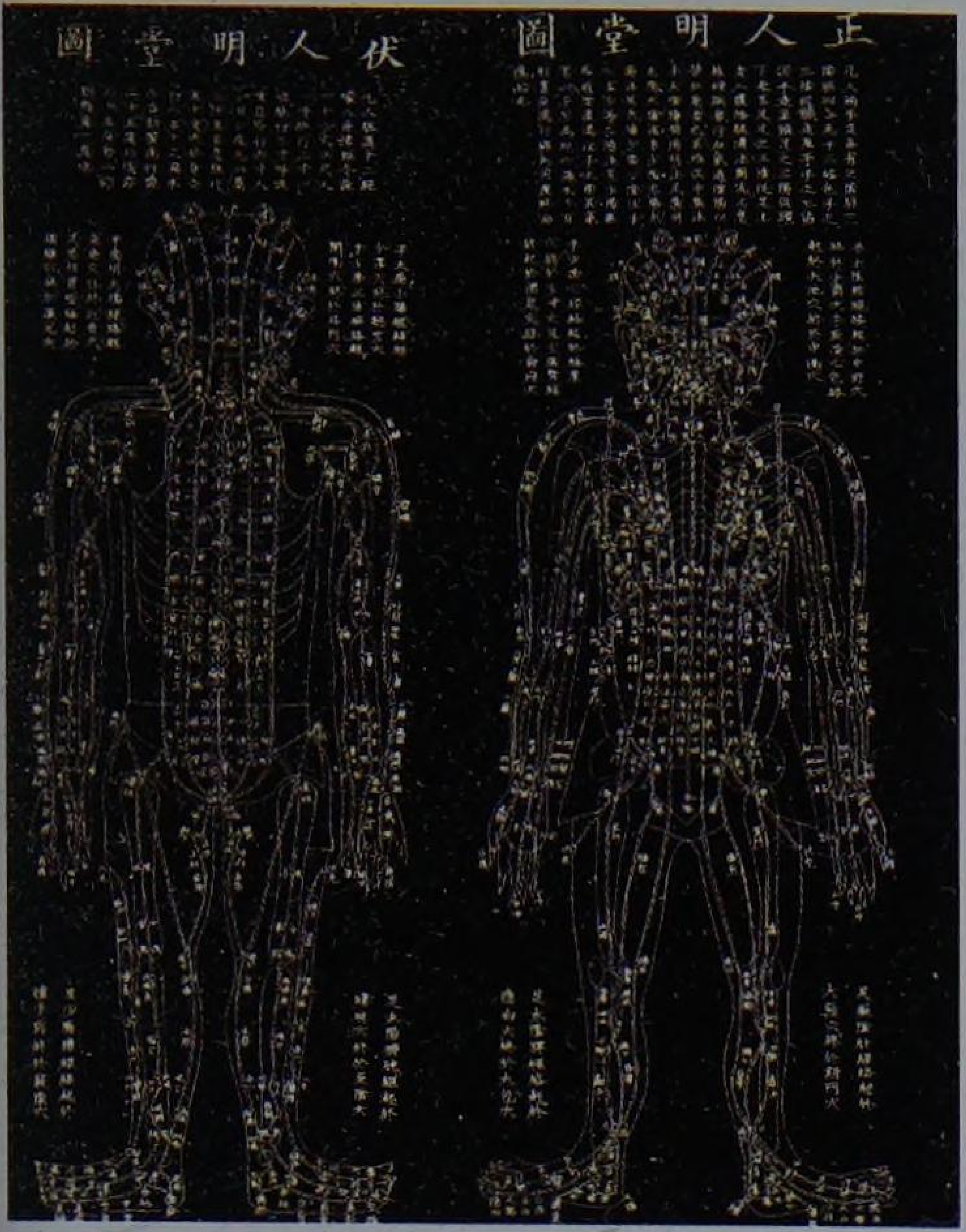
Surgical sacrifice
In the 14th and 15th centuries, the Aztecs who dominated Mexico believed the god Huitzilopochtli would make the sun rise and bring them success in battle, if offered daily blood, limbs, and hearts torn from living human sacrifices. From these grisly rituals, the Aztecs learned about the inner organs of the body.

Egyptian embalming
Some 5,000 years ago, the Egyptians believed that a dead body remained home to its owner's soul in the afterlife, but only if preserved as a life-like mummy. Natron, a type of salt, was used to dry out the body to embalm it and stop it rotting.

Internal organs, removed from an opening in the side, were preserved separately in special jars

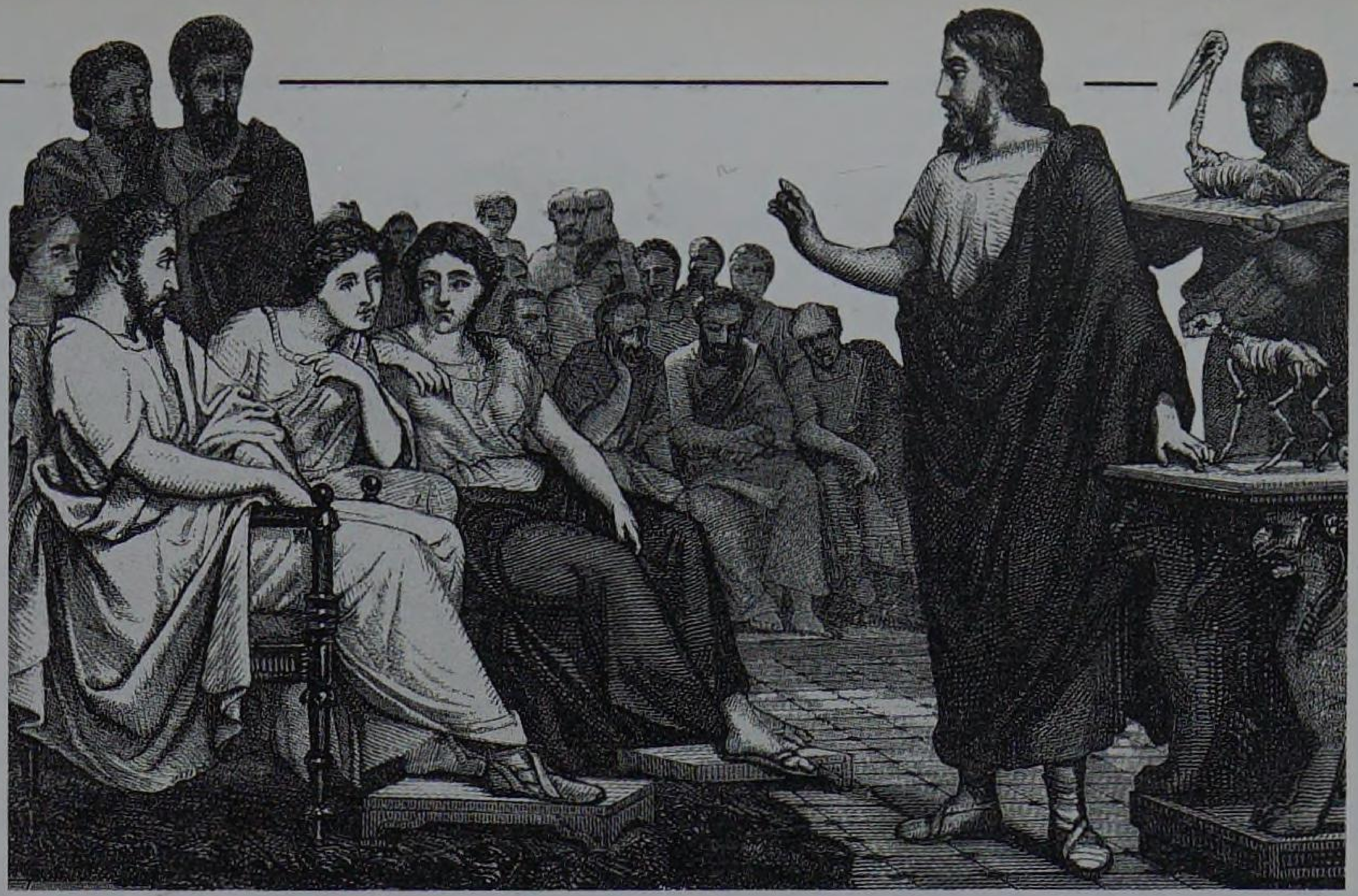
Brain, regarded as useless, was hooked out through the nostrils and discarded

Heart, seen as the centre of being, was left inside the chest



Chinese channels

Written over 2,300 years ago, *The Yellow Emperor's Classic of Internal Medicine* explains acupuncture treatments, which focus on the flow of chi, or vital energy, along 12 body channels, or meridians. Needles are inserted into the skin along these meridians to rebalance the body forces known as Yin (cool and female) and Yang (hot and male).



Claudius Galen

Born in ancient Greece, Claudius Galen became a towering figure in the study of anatomy, physiology, and medicine in Rome. There, he treated gladiators as a young physician, describing their wounds as "windows into the body". Human dissection was banned, so he studied the anatomy of animals instead. His flawed ideas were accepted without question for 1,500 years.

Medieval treatments

Blood-letting, using a knife or a blood-sucking worm called a leech, was a traditional, if brutal, remedy for all manner of ills in medieval times. Few physicians tried to see if the treatment was of any benefit to the patient

Galen remained a great influence in Europe and the Islamic world for many centuries

Hippocrates believed that physicians should act in their patients' best interests

Avicenna, the Persian anatomist, built on the teachings of the Romans and Greeks

Saving knowledge

This illustration comes from the 1610 translation of the *Canon Of Medicine*, written by the Persian physician Avicenna in c. 1025. He built on the knowledge of Galen and Hippocrates, whose medical works survived the fall of Rome only because they were taken to Persia, translated, and spread through the Islamic world. Their ideas were reintroduced to Europe after Islam spread to Spain in 711 CE.

Embalming process dried out the muscles, which shrank and exposed the bones

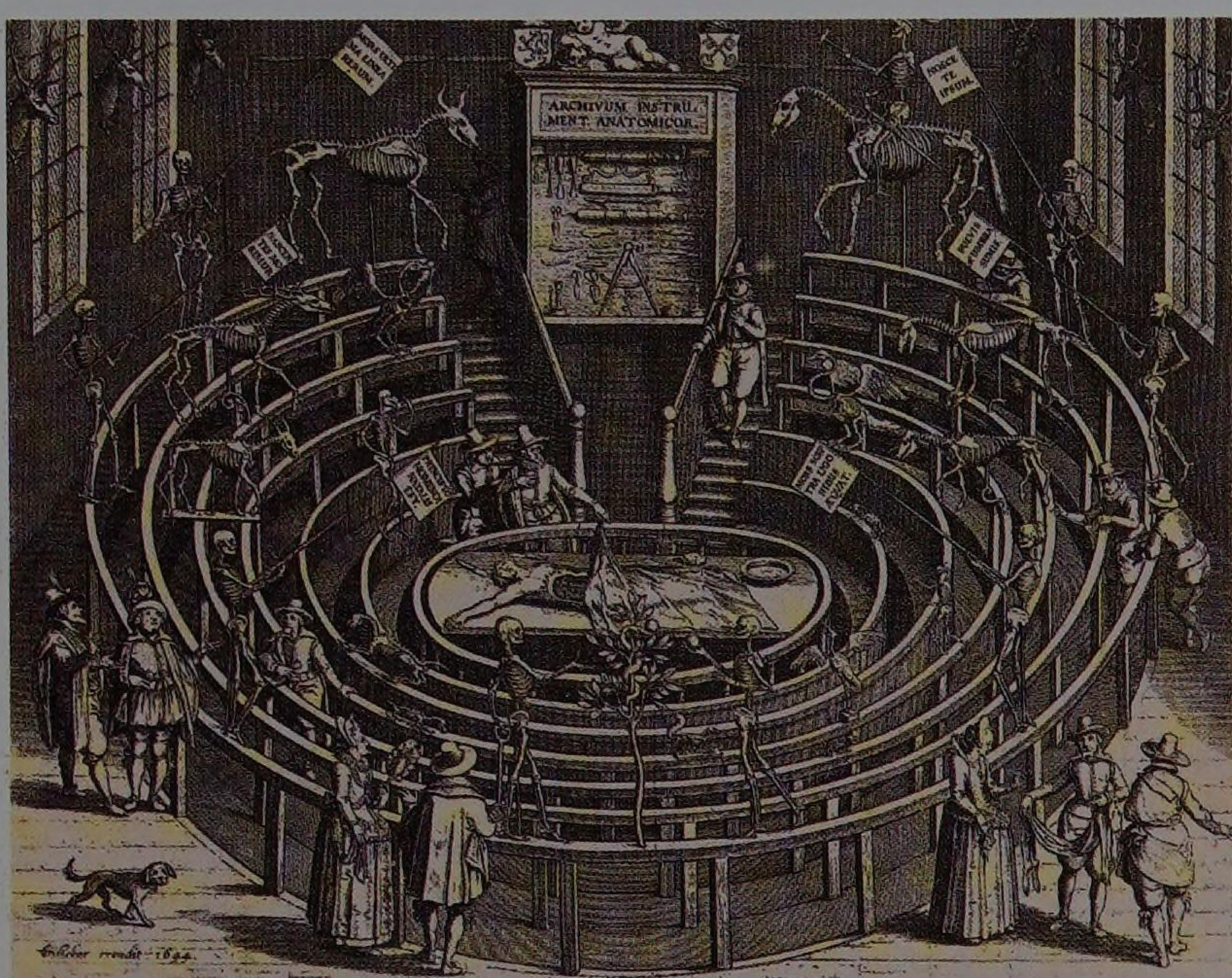
Skin became dark and leathery through embalming and age

Toenails, being made of dead cells, remained intact

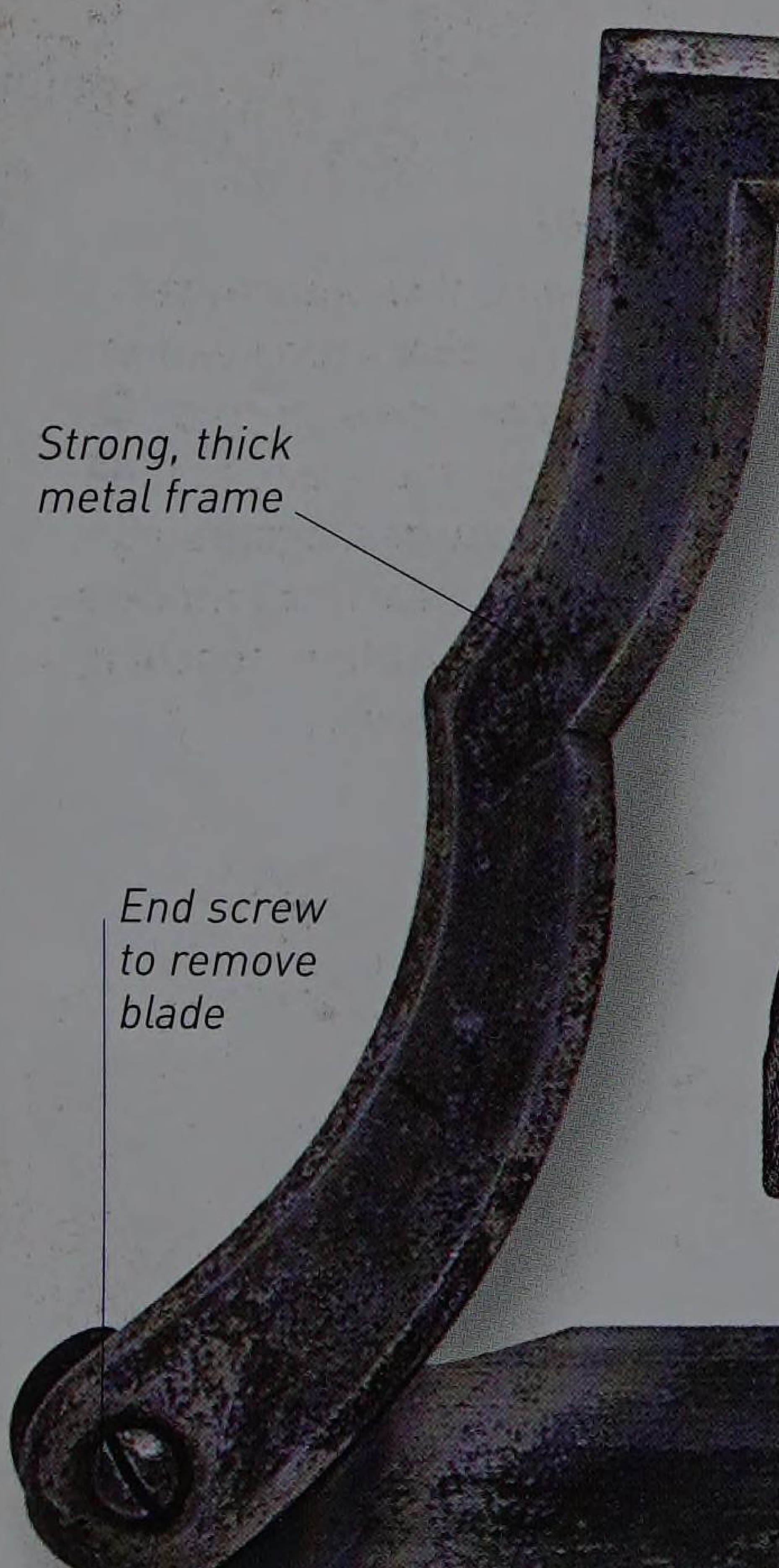
Respect for death
For many in the Middle Ages, life was less important than death and ascent into heaven. The body housed the soul, and must not be dissected. This anatomist risked being punished.

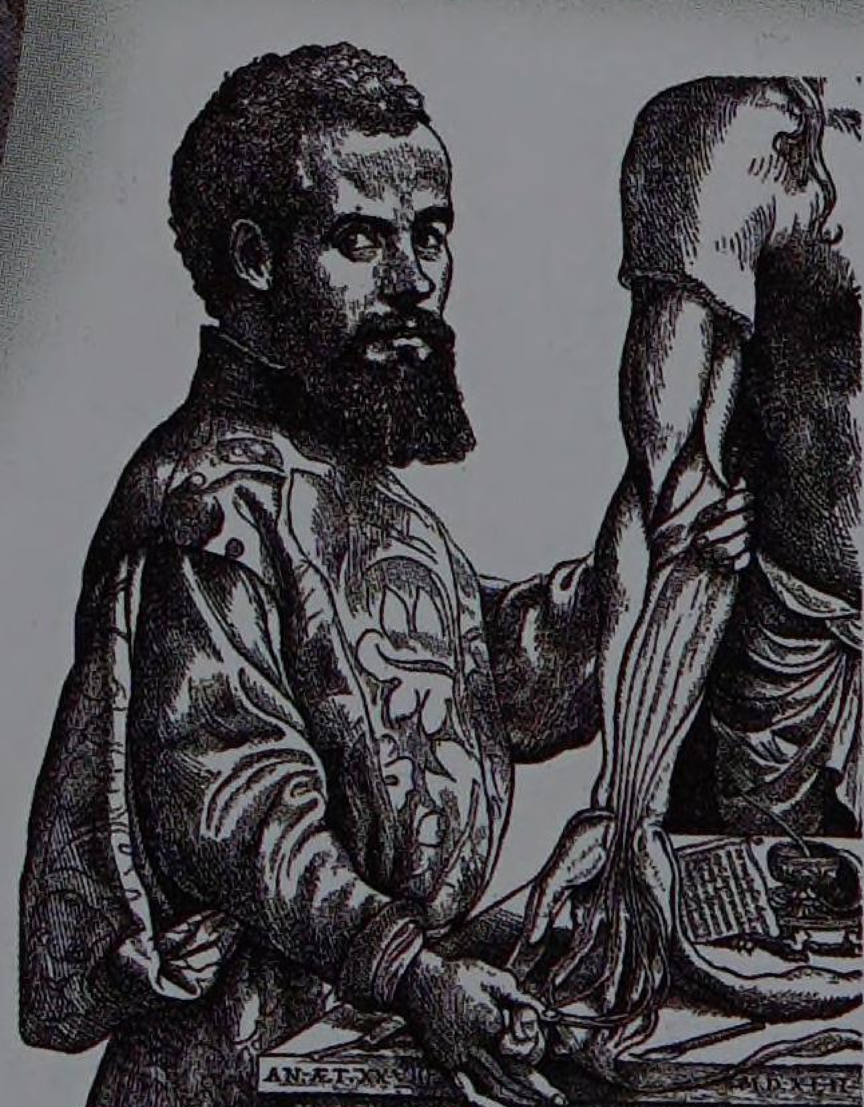
Study and dissection

A rebirth of the arts, architecture, and science spread across Europe between the 14th and 17th centuries. With the dawn of this Renaissance, the ban on human dissection, the precise cutting open of a body to study its internal structure was relaxed. In Italy, Andreas Vesalius (1514–64) performed careful, accurate dissections and drew his own conclusions, based on his observations, rather than blindly repeating the centuries-old accepted views. By questioning and correcting Galen's teachings, he revolutionized the science of anatomy and initiated a new era in medicine.

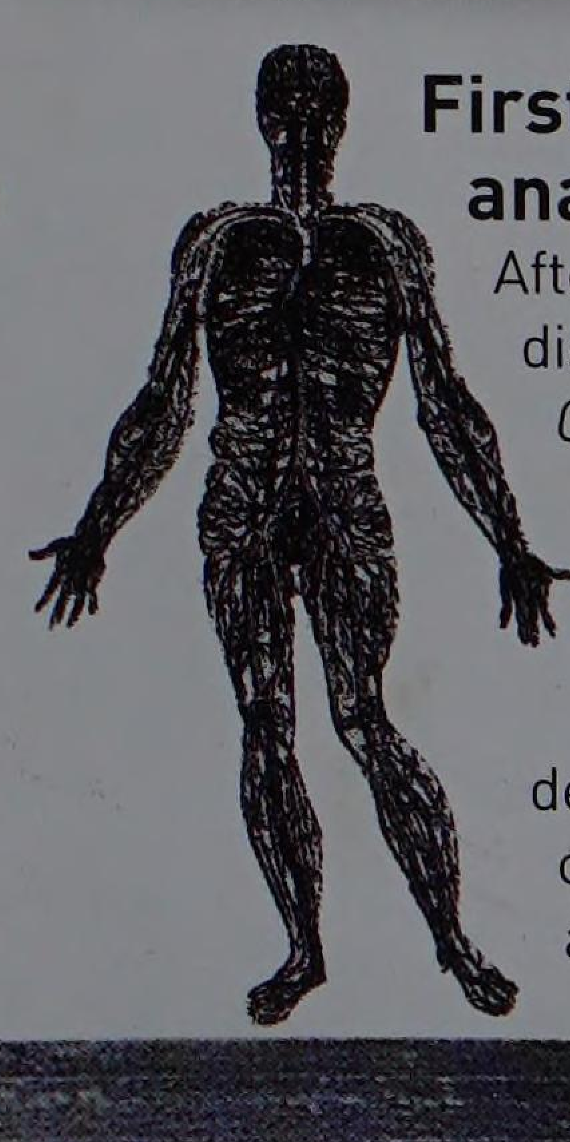


Anatomical theatre
Mondino dei Liuzzi (c. 1270–1326), a professor at Bologna, Italy introduced the public dissection of human corpses and is known as the Restorer of Anatomy. By the late 16th century, anatomical theatres were built at numerous universities. This 1610 engraving shows the anatomical theatre at Leiden, in the Netherlands. Spectators in the gallery looked down as the anatomy professor or his assistant carried out a dissection.

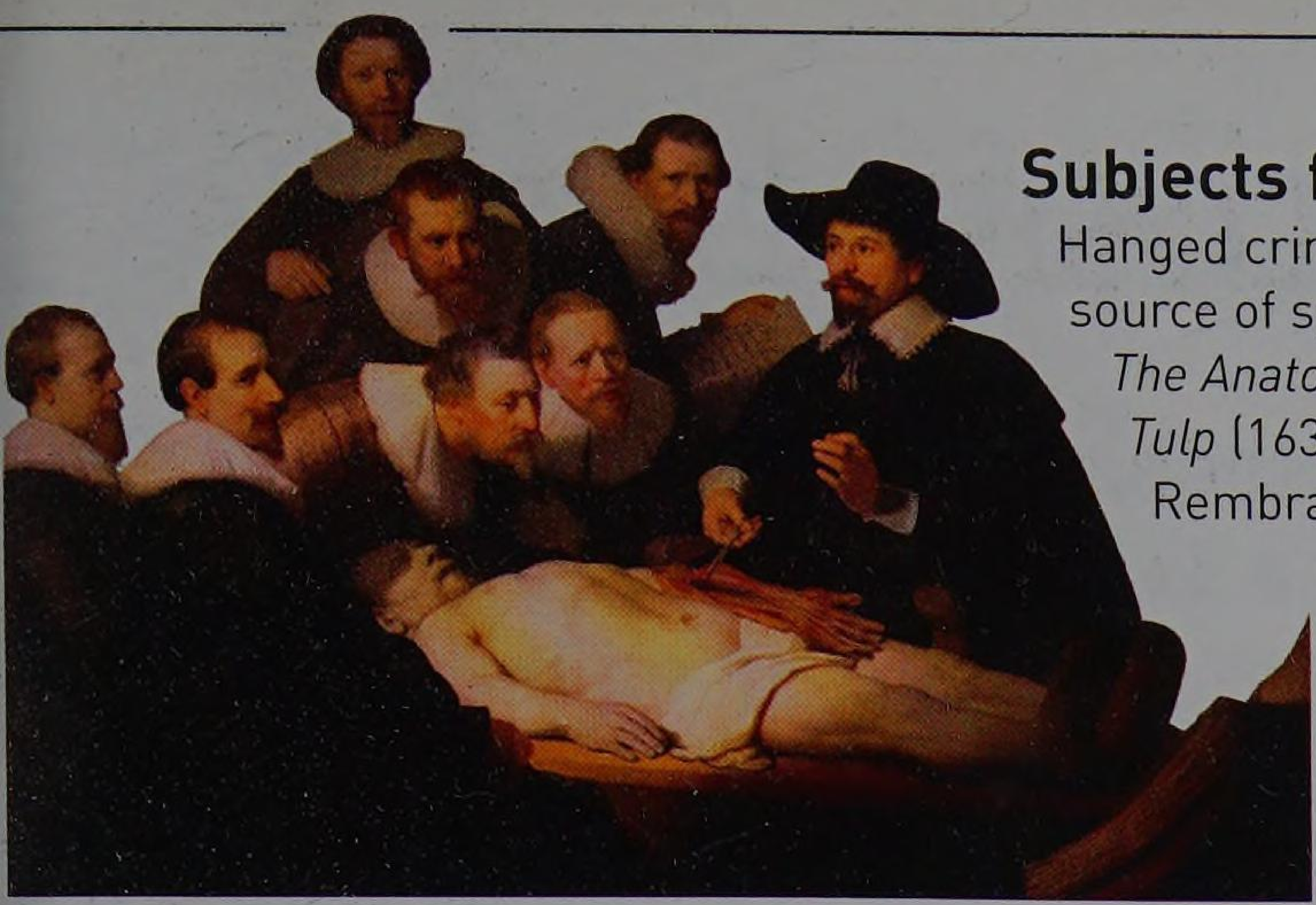




Break with tradition
Padua was at the forefront of Italian anatomy and medicine when Andreas Vesalius arrived in 1536. His exceptional skills were soon evident, and he soon became professor of anatomy. After translating early medical texts, Vesalius became dissatisfied with the teachings from ancient times. He preferred to believe what he saw in front of him, and set about writing his own book.



First scientific anatomy book
After four years of dissection Vesalius's *On the Structure of the Human Body* was published in 1543. The detailed text and lifelike-in-death illustrations caused sensation and outrage.



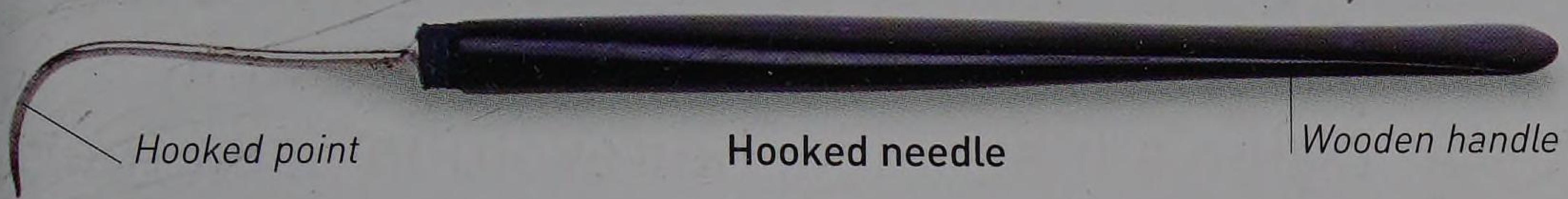
Subjects for study

Hanged criminals were a steady source of specimens for dissection. In *The Anatomy Lesson of Dr Nicholaes Tulp* (1632), by the Dutch artist Rembrandt, the dissection subject was robber Aris Kindt. Anatomy lessons were training for physicians and surgeons, and were open to any interested members of the public.

Women and anatomy

Until the 19th century, women took on only very minor medical roles, except as midwifes. These Swedish women learning anatomy, in a photograph from about 1880, are probably training for midwifery.

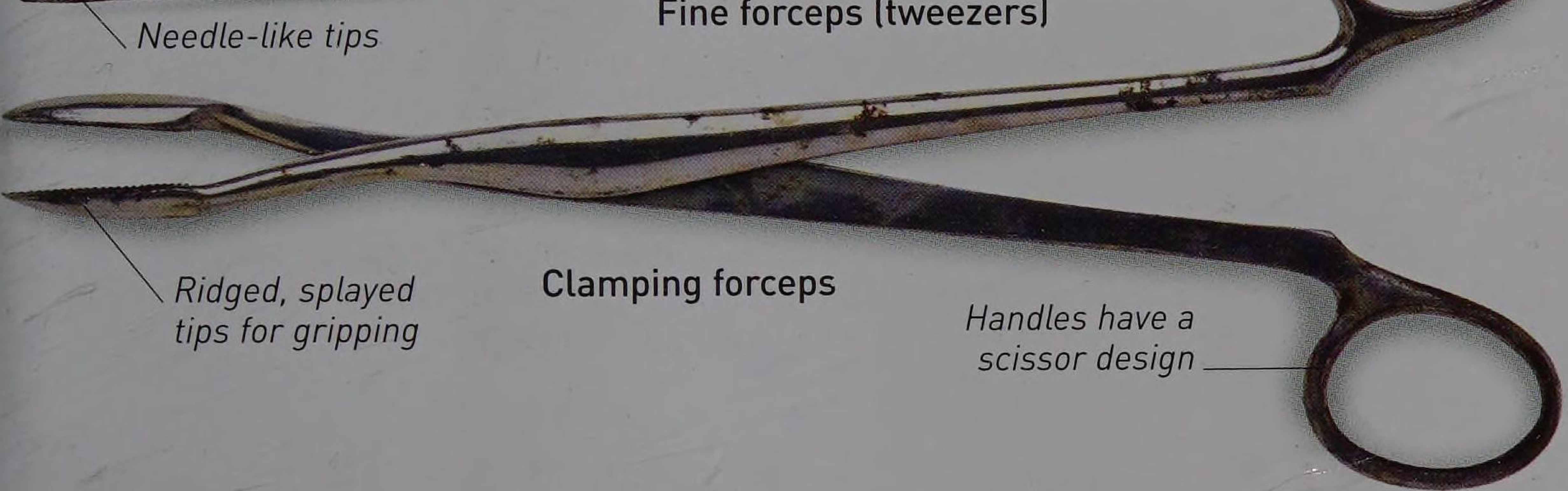
Double-ended small probe



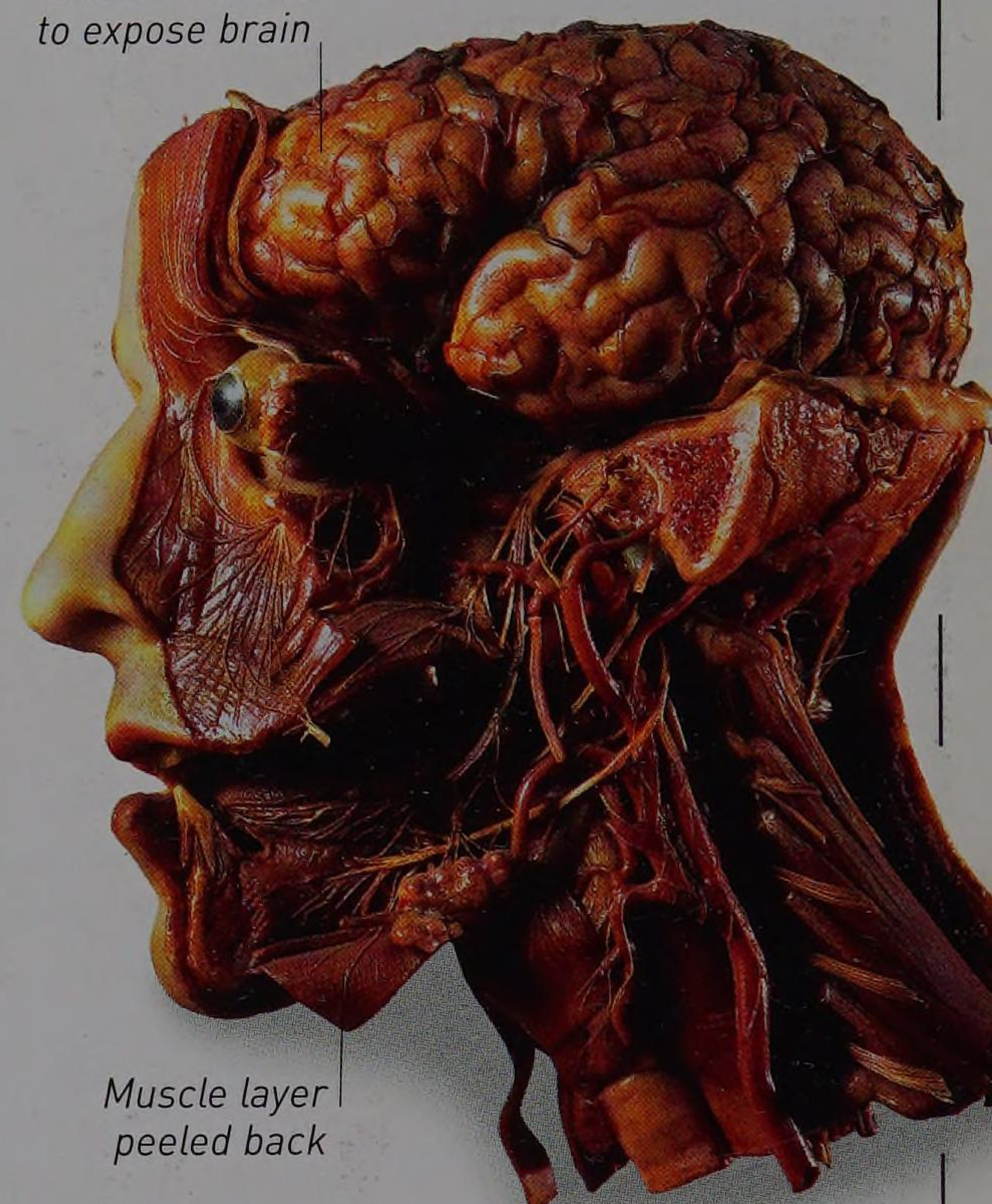
Hooked needle

Scalpel

Fine forceps (tweezers)



Clamping forceps

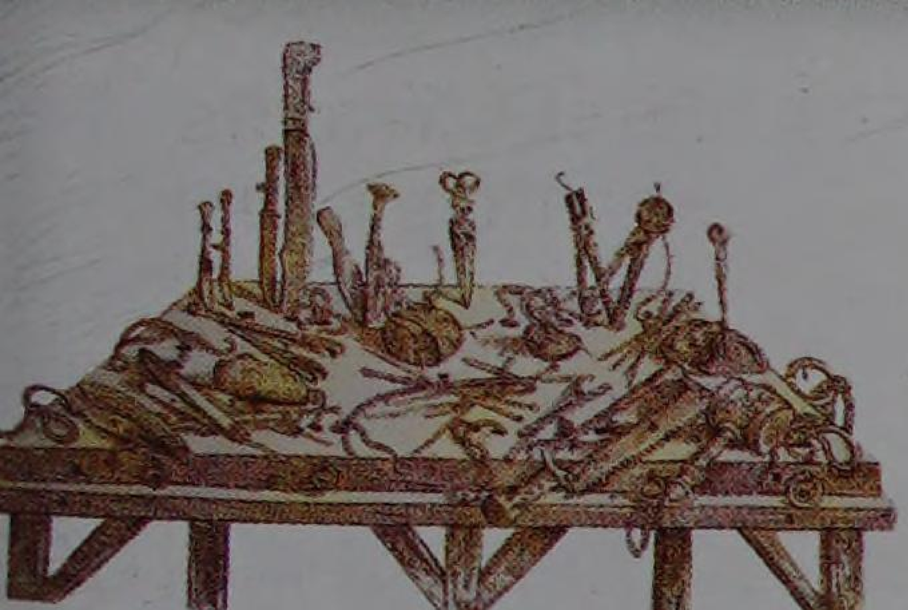


Tools of the trade

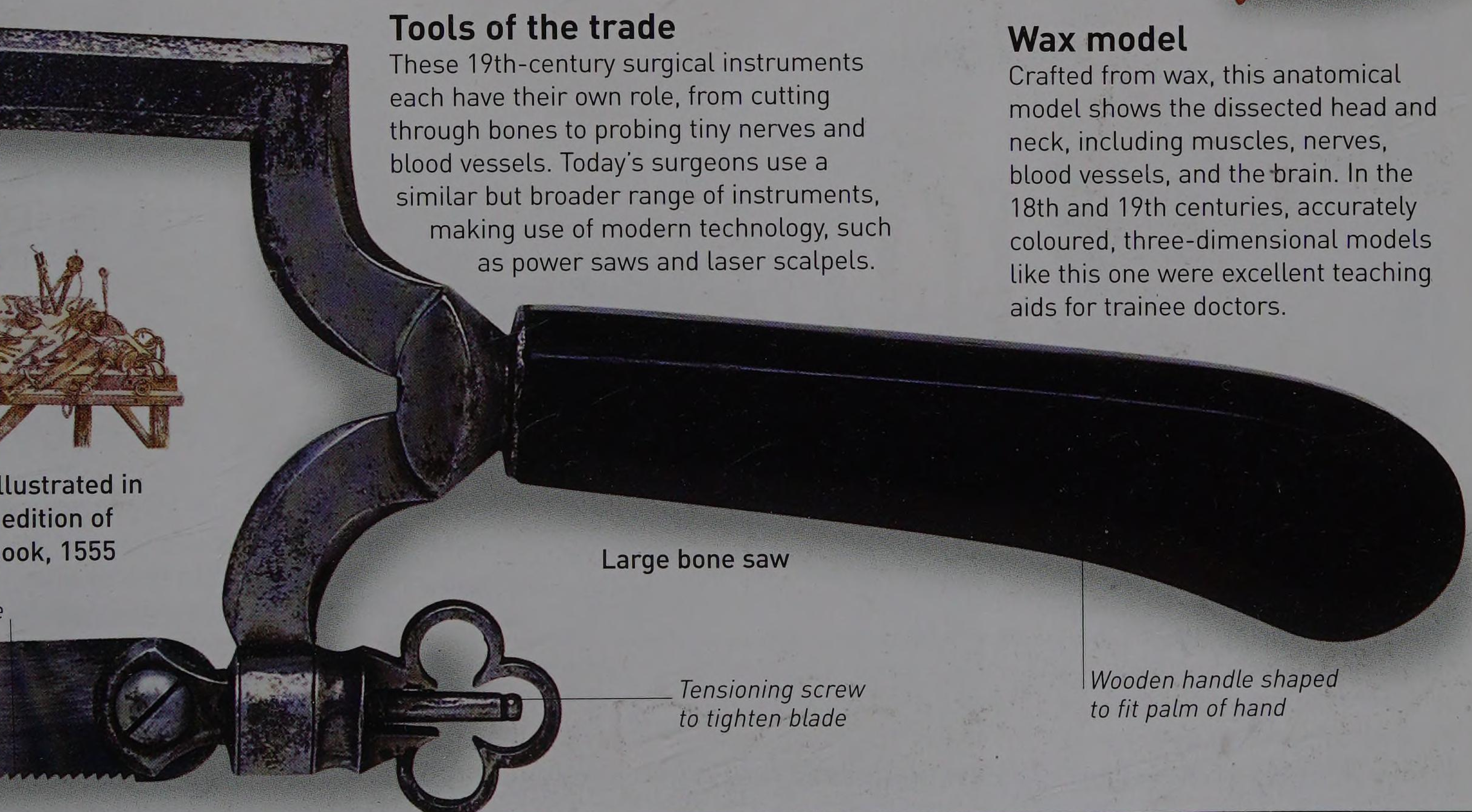
These 19th-century surgical instruments each have their own role, from cutting through bones to probing tiny nerves and blood vessels. Today's surgeons use a similar but broader range of instruments, making use of modern technology, such as power saws and laser scalpels.

Wax model

Crafted from wax, this anatomical model shows the dissected head and neck, including muscles, nerves, blood vessels, and the brain. In the 18th and 19th centuries, accurately coloured, three-dimensional models like this one were excellent teaching aids for trainee doctors.

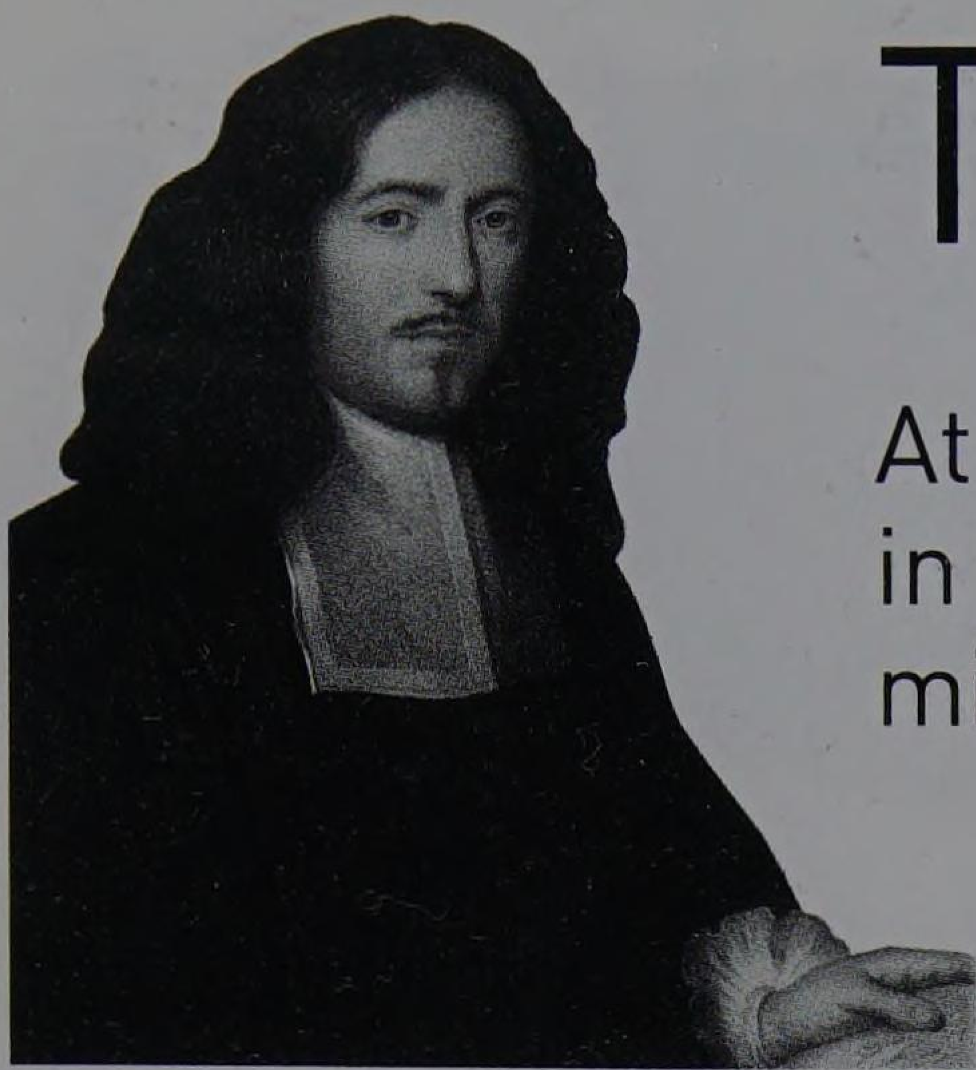


Instruments illustrated in the second edition of Vesalius's book, 1555



Large bone saw

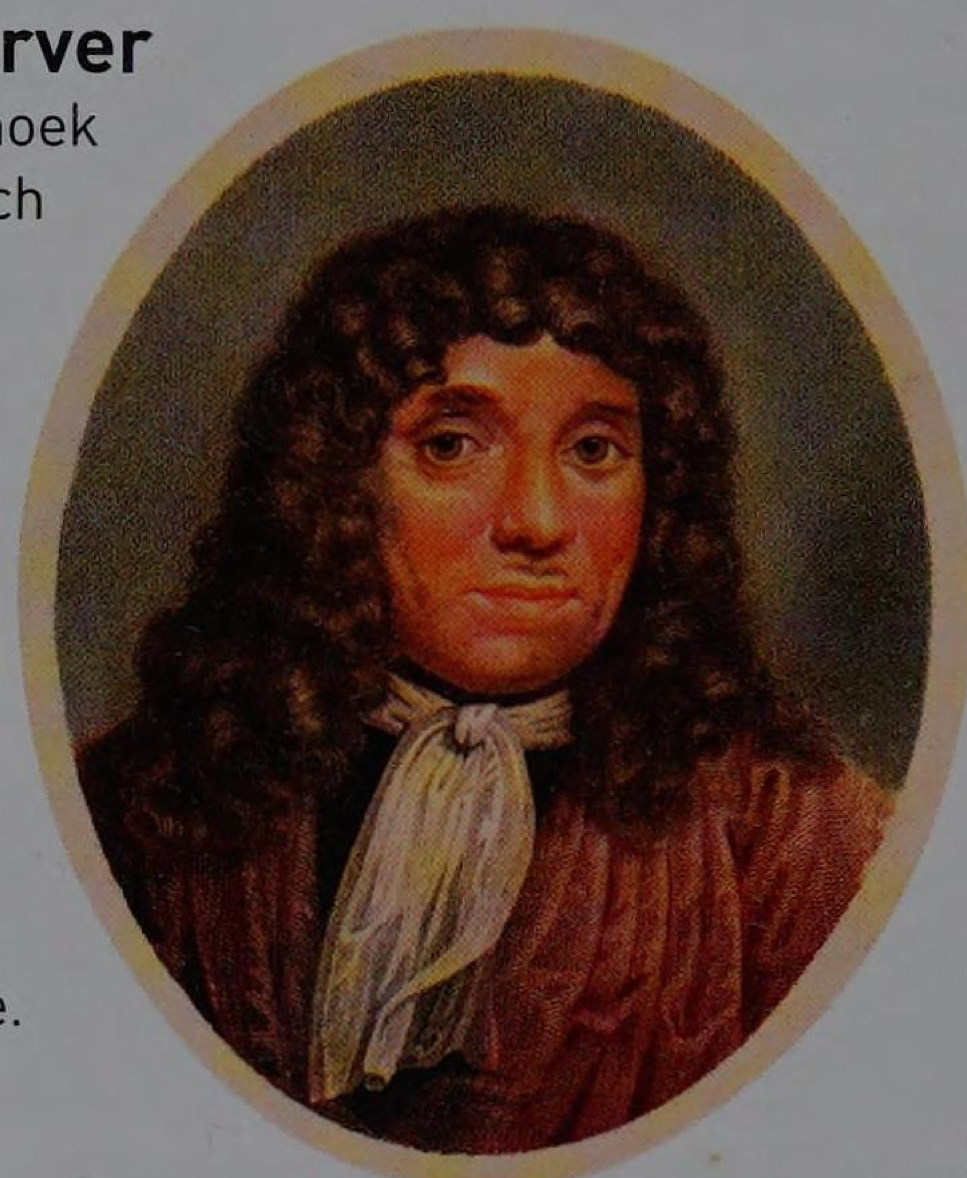
The microscopic body



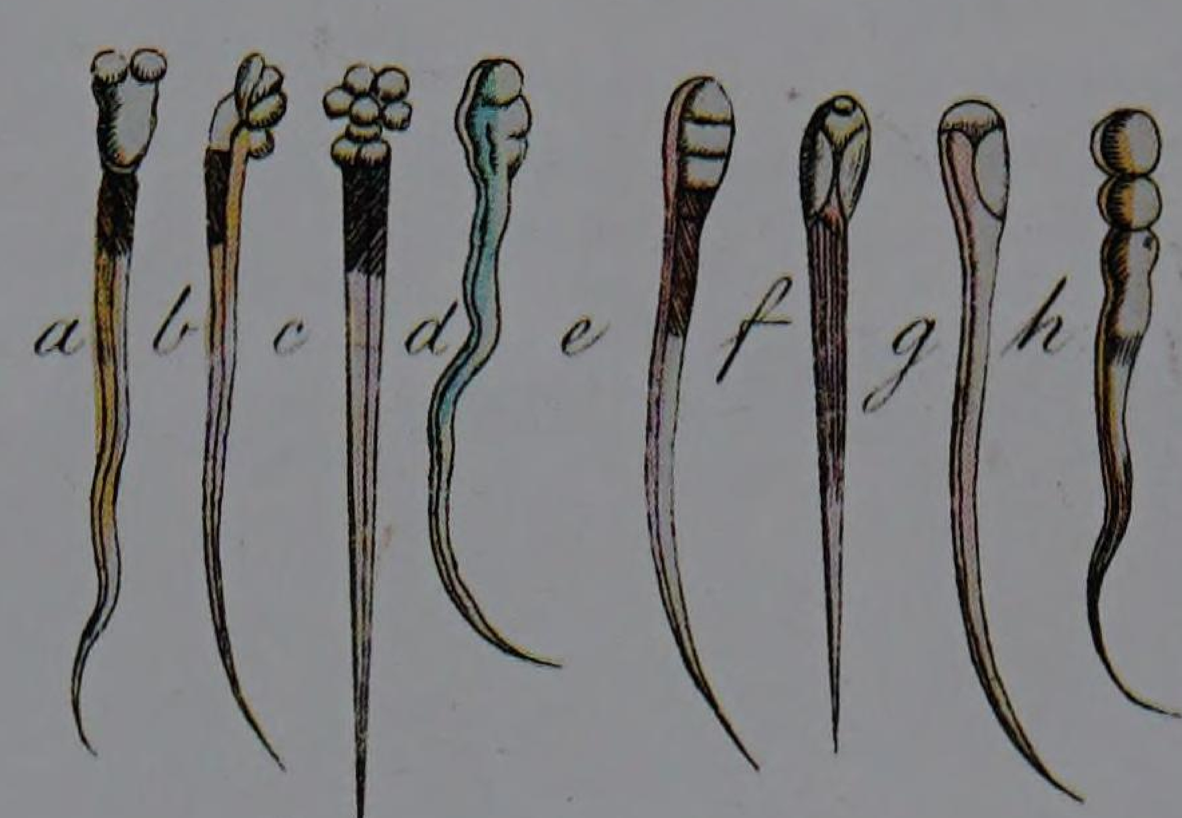
Pioneer histologist
Italy's Marcello Malpighi (1628–94) was the founder of microscopic anatomy and a pioneer of histology, the study of tissues. He was the first to identify capillaries, the tiny blood vessels that connect arteries to veins.

At the beginning of the 1600s, scientific instrument makers in the Netherlands invented a magnifying device called the microscope. For the first time, scientists used high-quality glass lenses to view objects, illuminated by light, which previously had been far too small to see with the naked eye. Pioneering microscopists showed that living things are made up of much smaller units, which Robert Hooke (1635–1703) likened to the cells, or rooms, of monks in a monastery. The term "cells" has been used ever since.

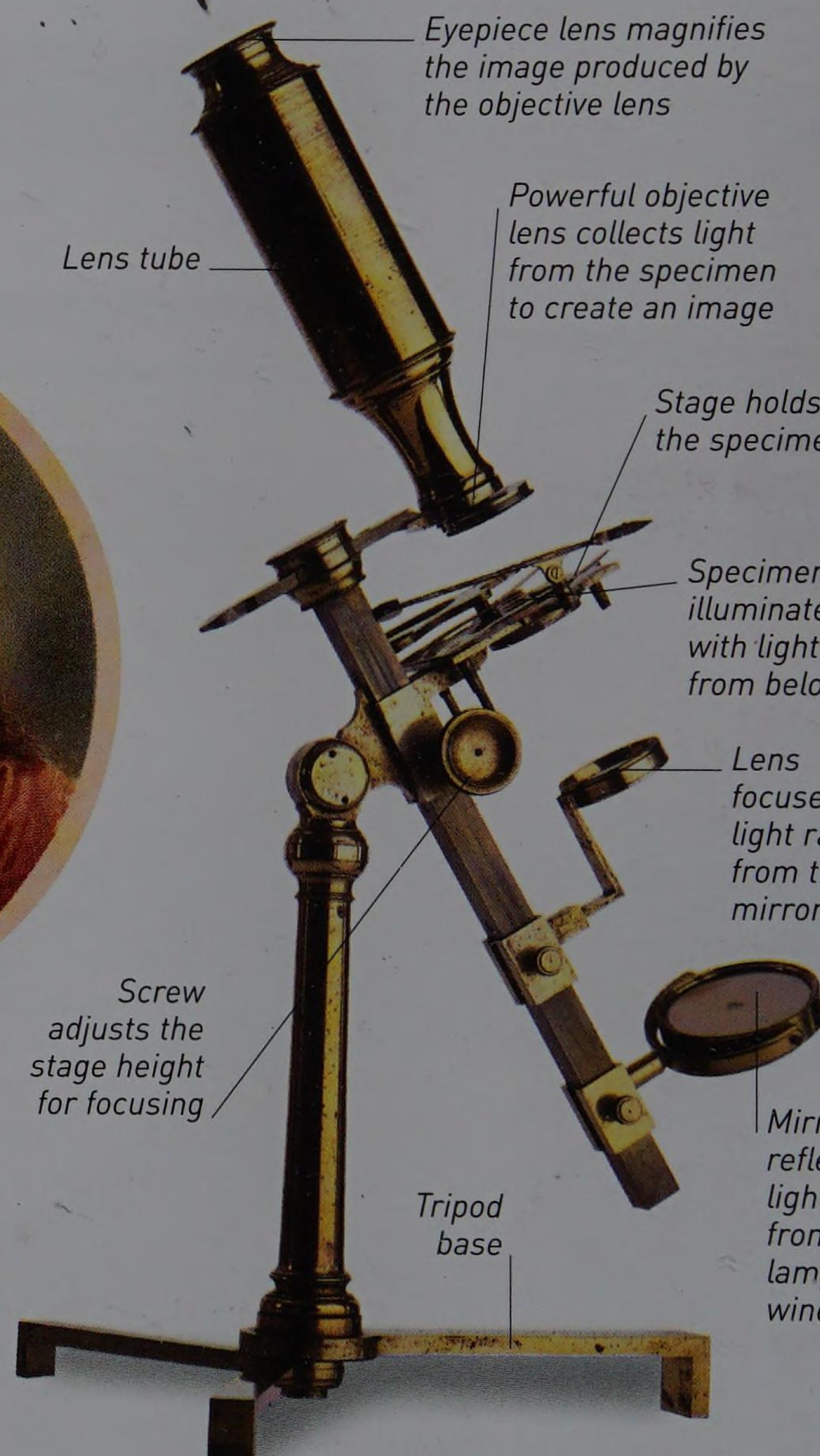
Home-made lenses
In van Leeuwenhoek's day, most microscopes had two lenses, as shown on the right. His version, shown life-size above, had one tiny lens, yet it enabled him to observe cells, tissues, and tiny organisms magnified up to 275 times. He made about 400 microscopes, and helped to establish microscopy as a branch of science.



Wide-ranging observer
Antoni van Leeuwenhoek (1632–1723) was a Dutch cloth merchant and self-taught scientist. With his homemade microscopes Leeuwenhoek was the first to observe, among many other things, blood cells and sperm. In 1683 he also spotted, in scrapings from his own teeth, the first bacteria seen by the human eye.



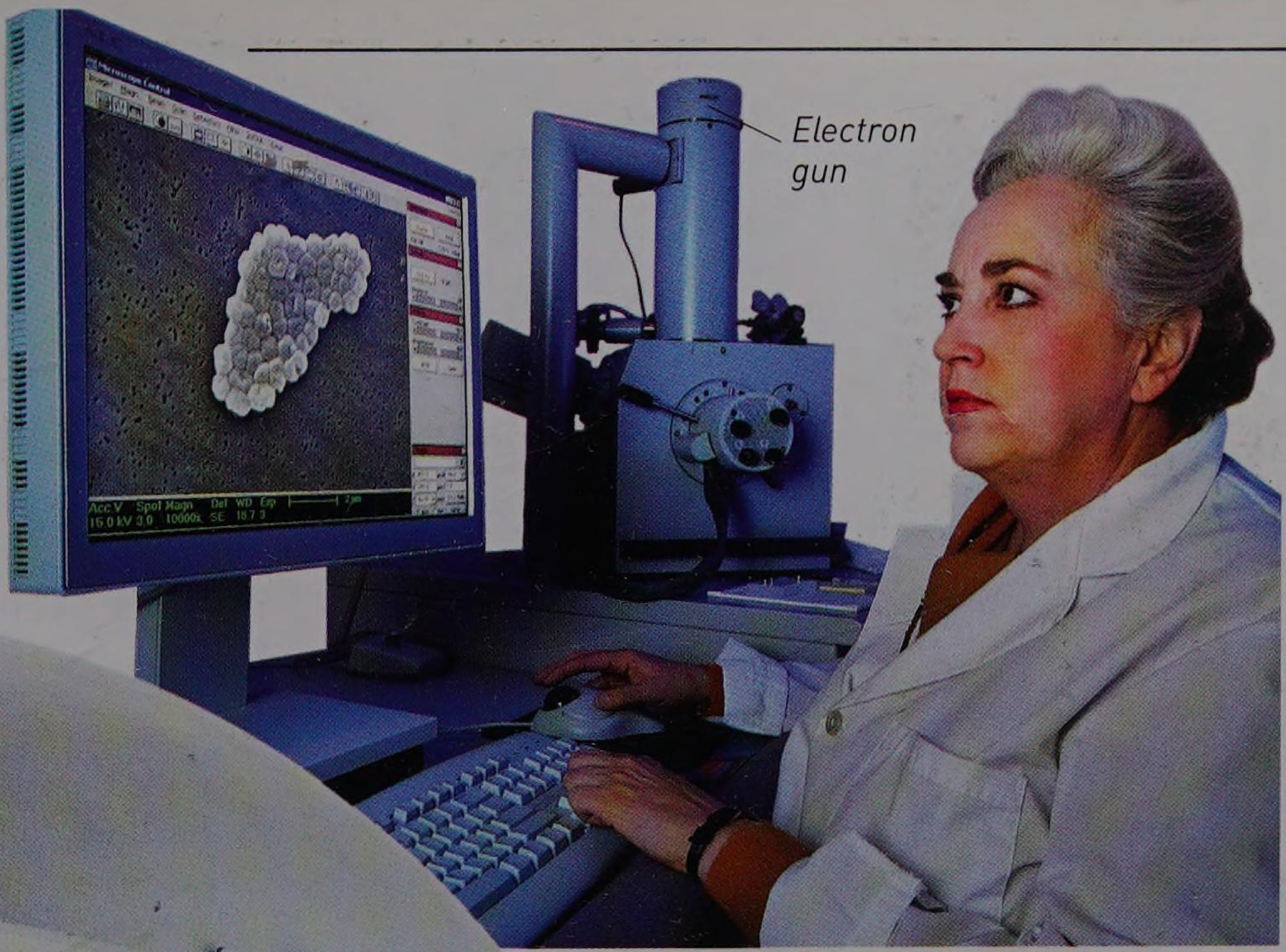
Microscopic drawings
Today, photography can capture what is viewed under the microscope. Early microscopists used drawings and writing to record what they had seen. This drawing by van Leeuwenhoek records his observation, for the first time, of sperm cells.

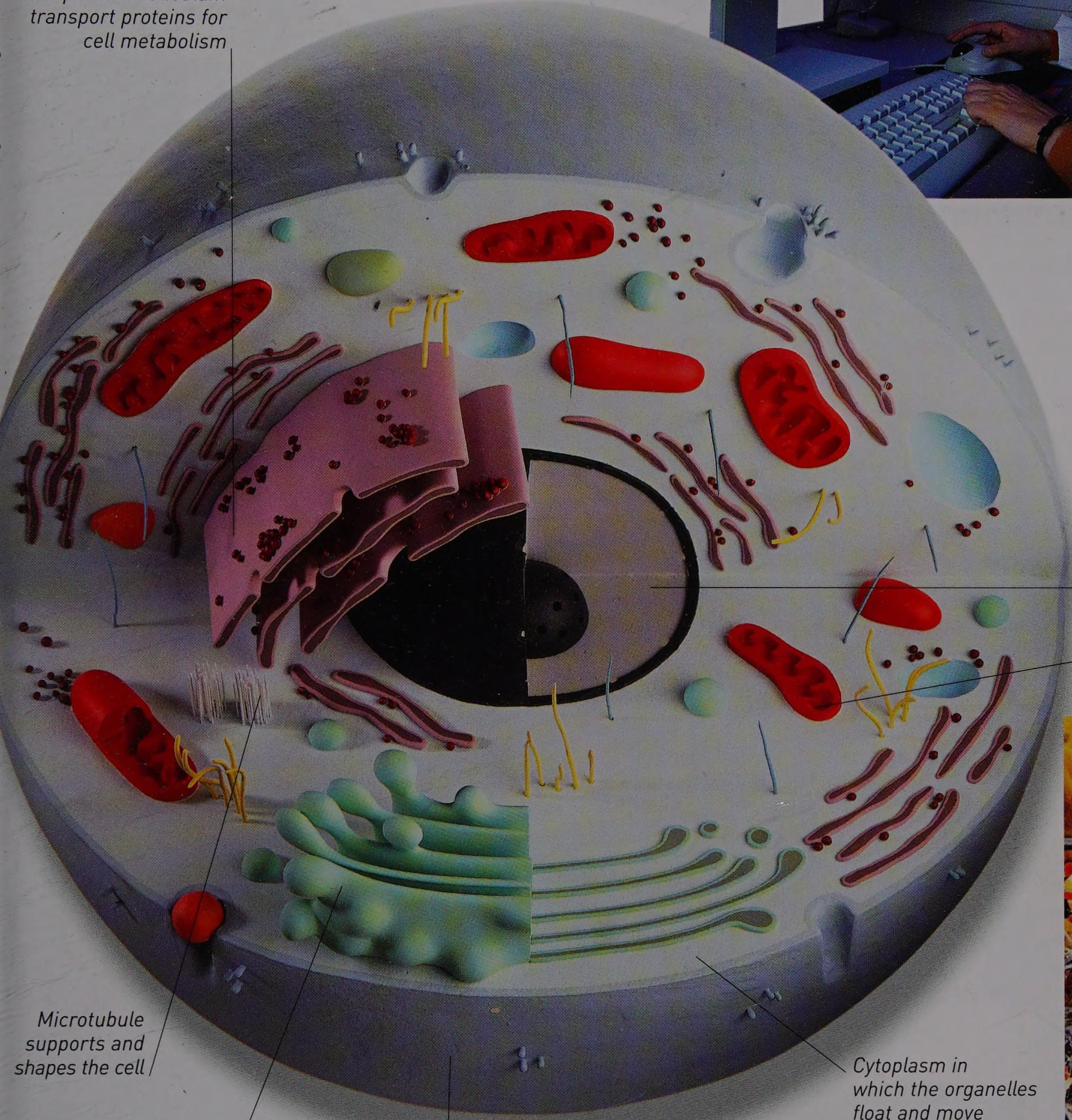


Compound microscope
Van Leeuwenhoek's "simple" microscopes had only one lens. Most light microscopes, which use light for illuminating the specimen, are compound, using two or more lenses. This 19th-century model has the basic features found on a modern compound microscope. The specimen is sliced thinly enough for light to be shone through it and up through the lenses to the eye.

Inside a cell

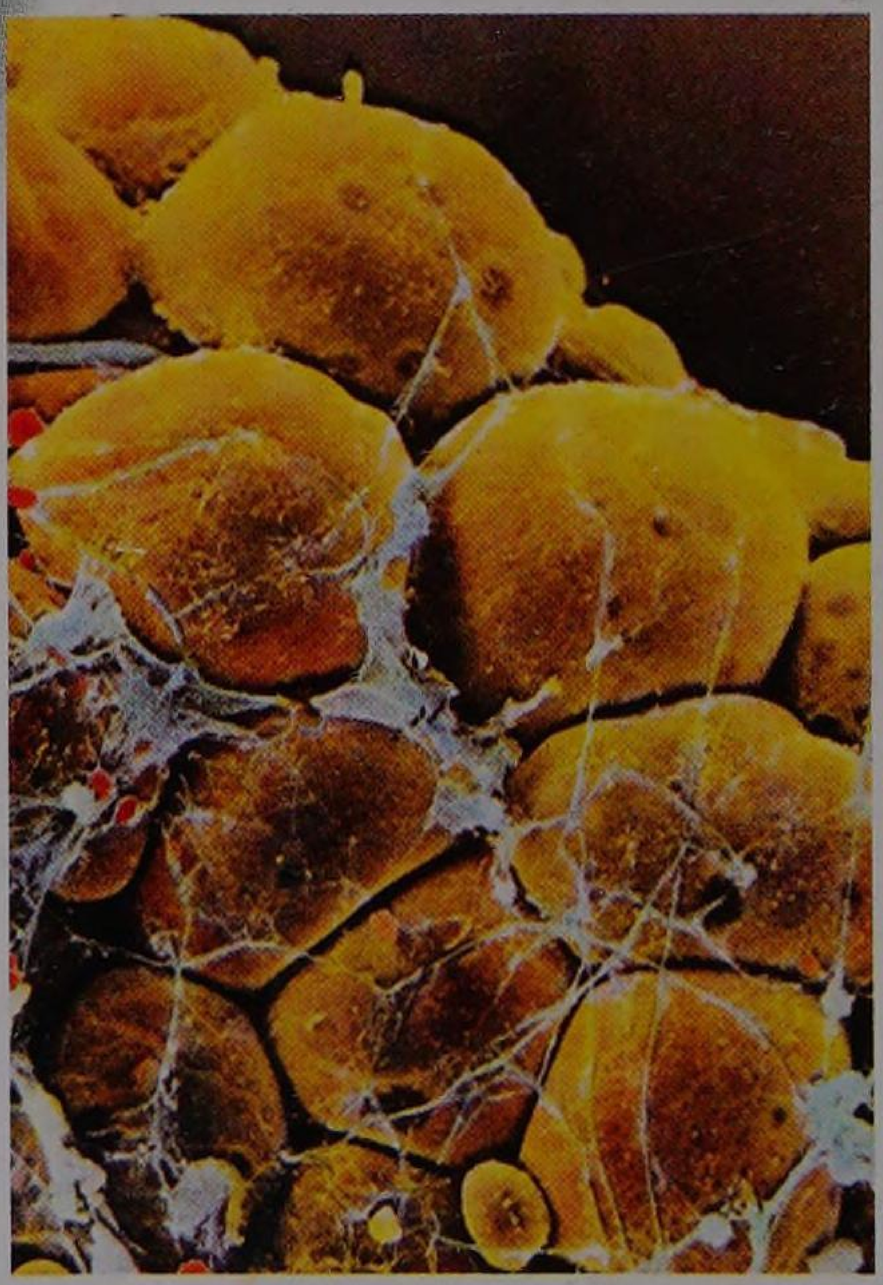
This cutaway model of a typical human cell shows the parts of a cell that can be seen using an electron microscope. A thin cell membrane surrounds the cell. The jelly-like cytoplasm contains organelles (small organs), each with a supporting role. The nucleus, the largest structure within the cell, contains the instructions needed to run the cell.





Electron microscope

An electron microscope uses minute parts of atoms called electrons to magnify thousands or millions of times. Focused by magnets, an electron beam is fired towards a specimen at the base. Electrons that pass through or bounce off the specimen are detected and create an image on a monitor.



Surface view

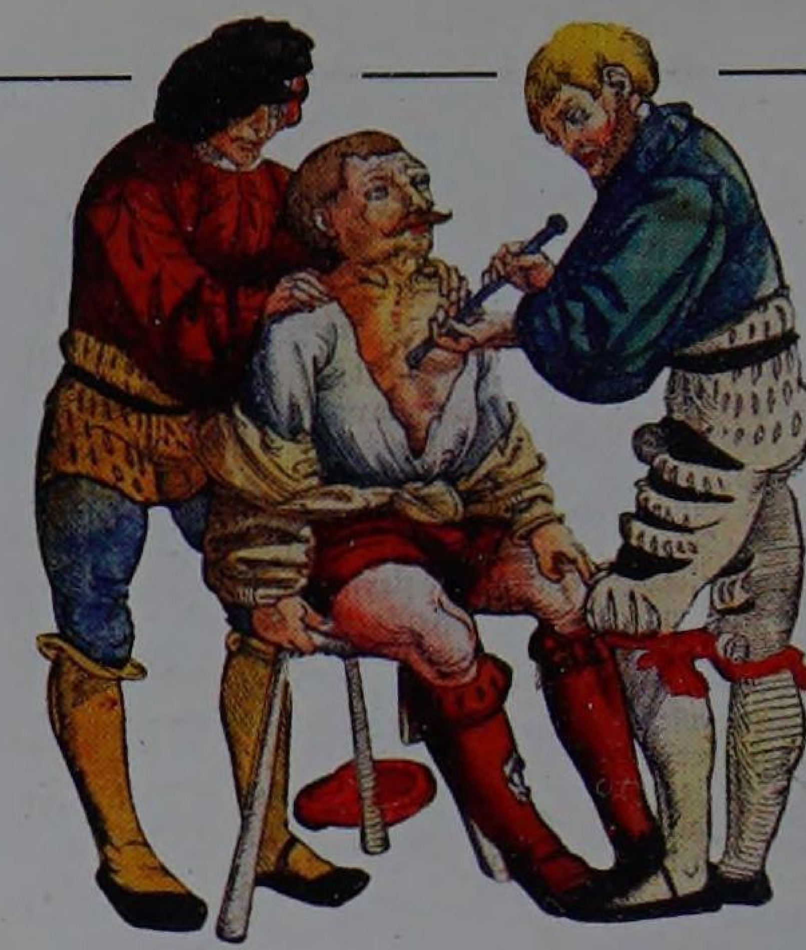
In a scanning electron microscope, an electron beam scans the surface of a whole specimen. Electrons bouncing off the specimen are focused to produce a black-and-white, three-dimensional image. This scanning electron micrograph (SEM) shows fat cells.

Cell slice

A transmission electron microscope projects an electron beam through a slice of body tissue onto a monitor. The image is photographed to produce a transmission electron micrograph. This TEM shows a liver cell's mitochondria (white), and endoplasmic reticulum (blue).

Looking inside the body

In the past, the only way to see inside the body was to cut it open or inspect soldiers' wounds. The invention of the ophthalmoscope in 1851 allowed doctors to view the inside of a patient's eye for the first time. In 1895, X-rays were discovered and used to produce images of bones without cutting open the body. Today's imaging techniques allow us to view tissues, search for signs of disease, and find out how the body works.



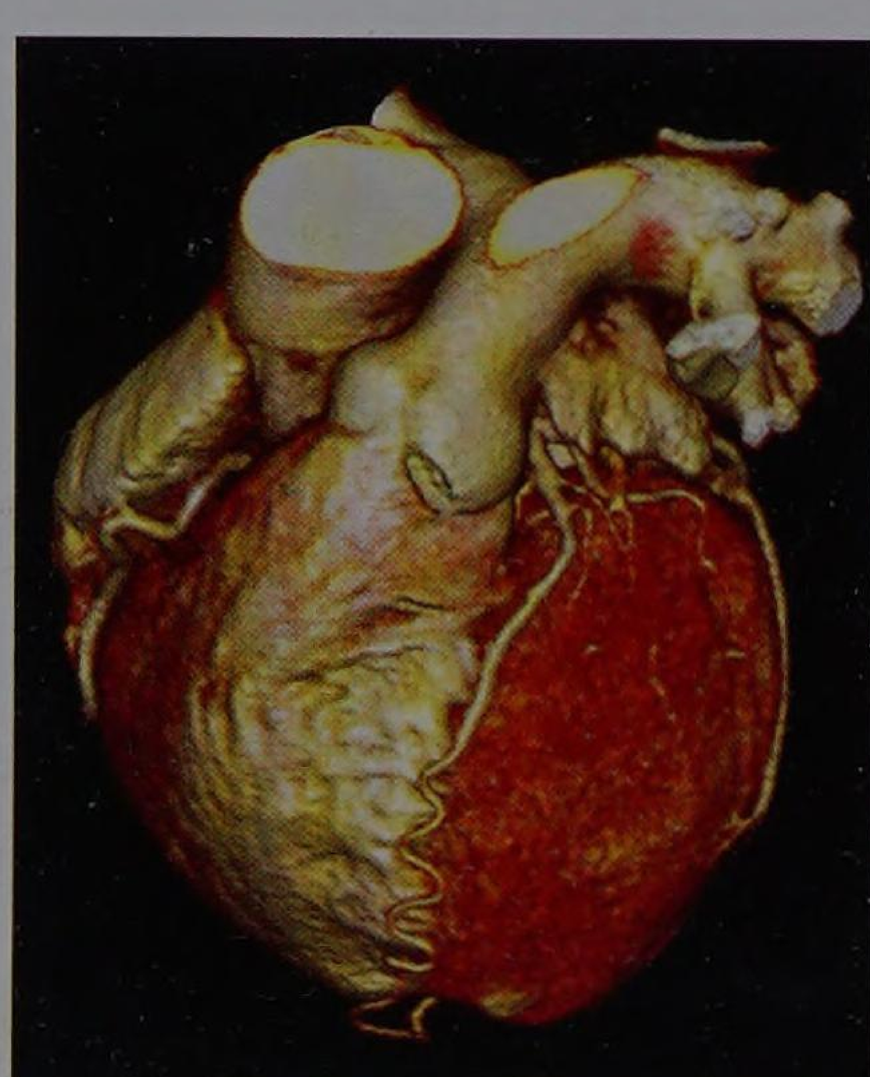
War wounds
This illustration from a German medical manual of 1540 shows surgeons how to extract an arrowhead from a soldier on the battlefield.

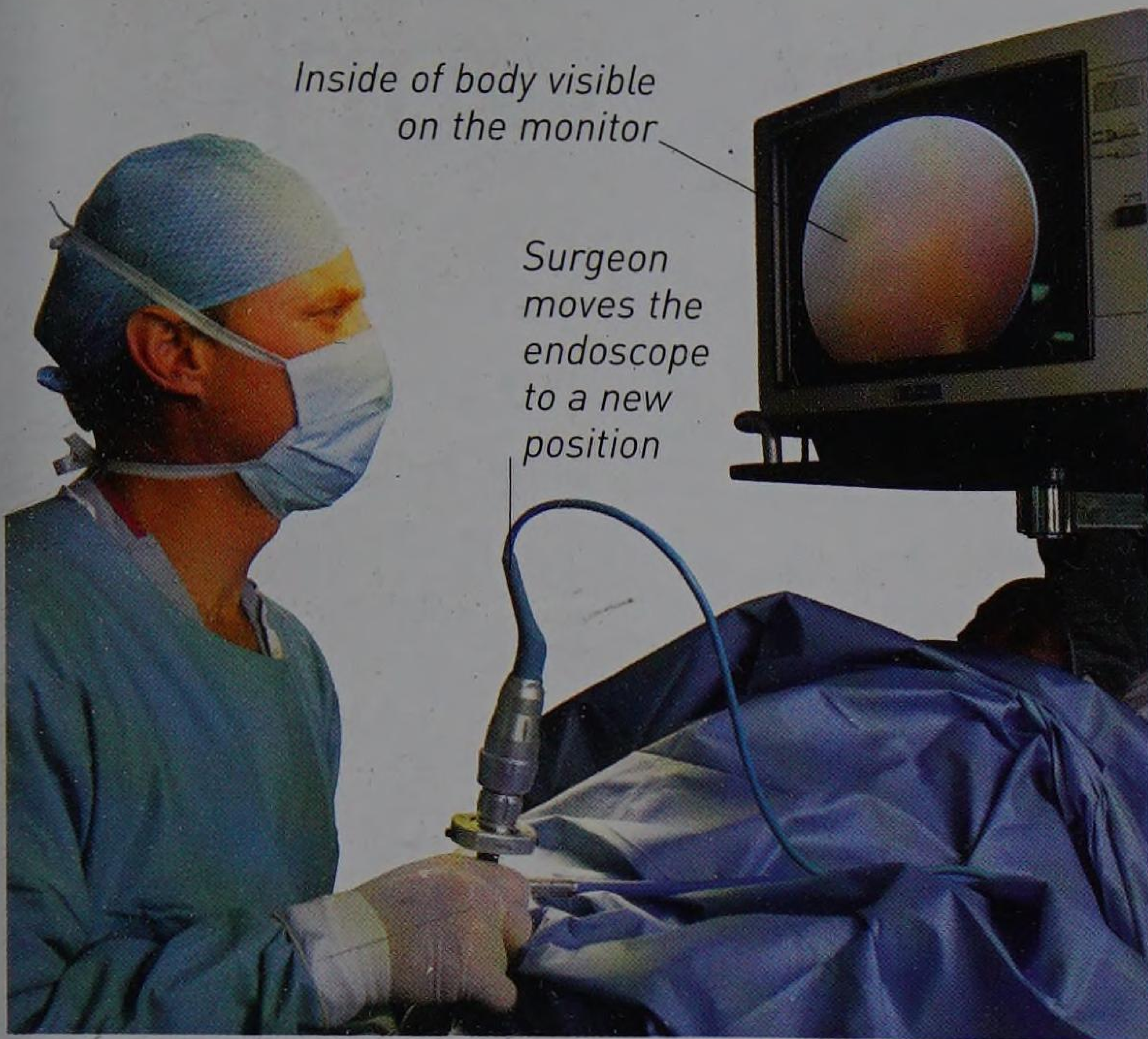
Mysterious rays
This radiograph from 1896 was produced by projecting X-rays (a form of radiation) through a woman's hand onto a photographic plate. Hard bones and metal show up clearly since they absorb X-rays that pass through softer tissues.

Opthalmoscope

Medical viewing kit
Today's doctors routinely use this multipurpose medical equipment when examining patients in the surgery. The kit consists of a handle, which contains batteries to power a light source, and a range of attachments used for looking inside the ears, throat, nose, or eyes. For example, using the ophthalmoscope attachment, a doctor can shine a light and look into a patient's eye.

CT scanning
A computed tomography (CT) scan uses X-rays and a computer to look inside the body. A patient lies inside a rotating scanner, which sends a narrow beam of X-rays through the body to a detector. The result is a two-dimensional slice of the body showing hard and soft tissues. A computer combines image slices together to build up a three-dimensional picture of a body part, such as this living heart.



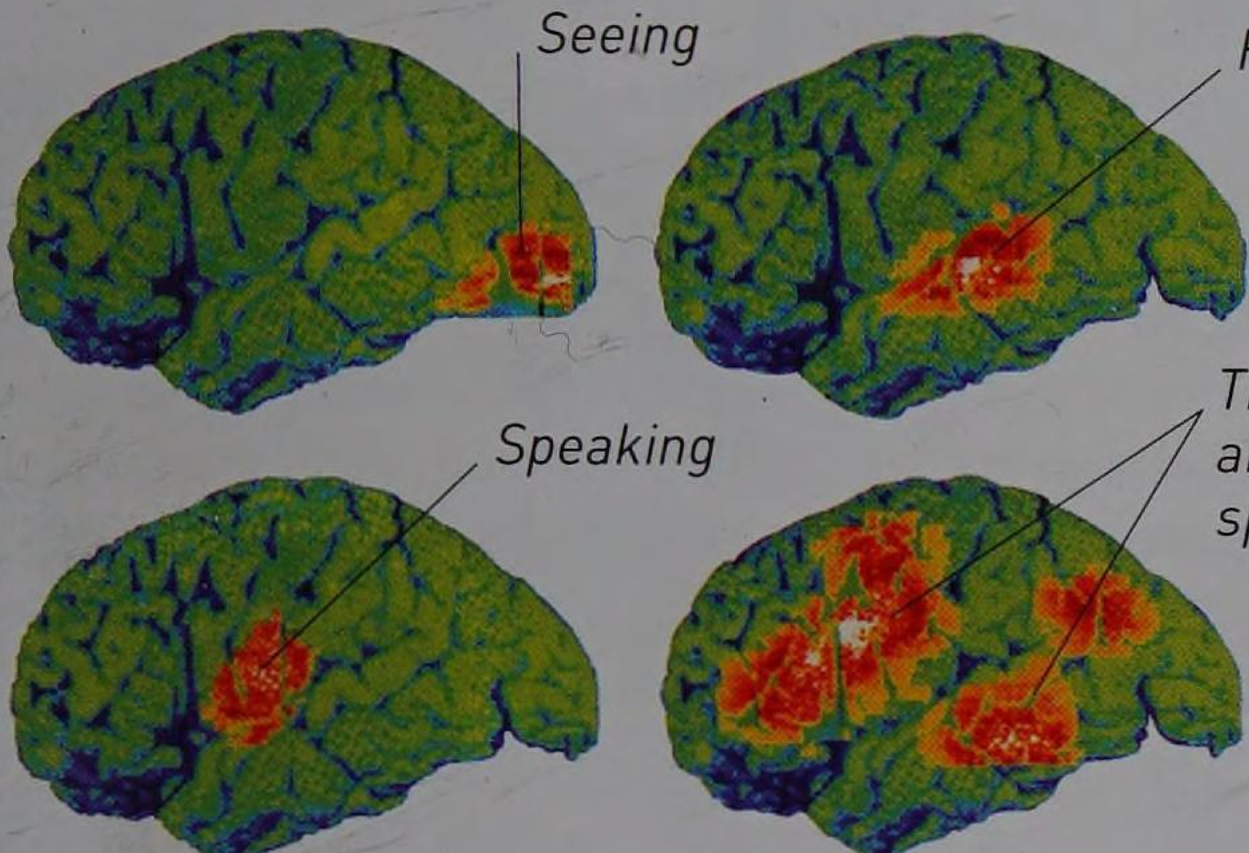


Endoscope

Surgeons use a thin, tube-like endoscope to examine tissues and to look inside joints. It is inserted via a natural body opening, such as the mouth, or a small incision in the skin (as shown here). Optical fibres inside the tube carry bright light to illuminate the inside of the body and send back images to a monitor.

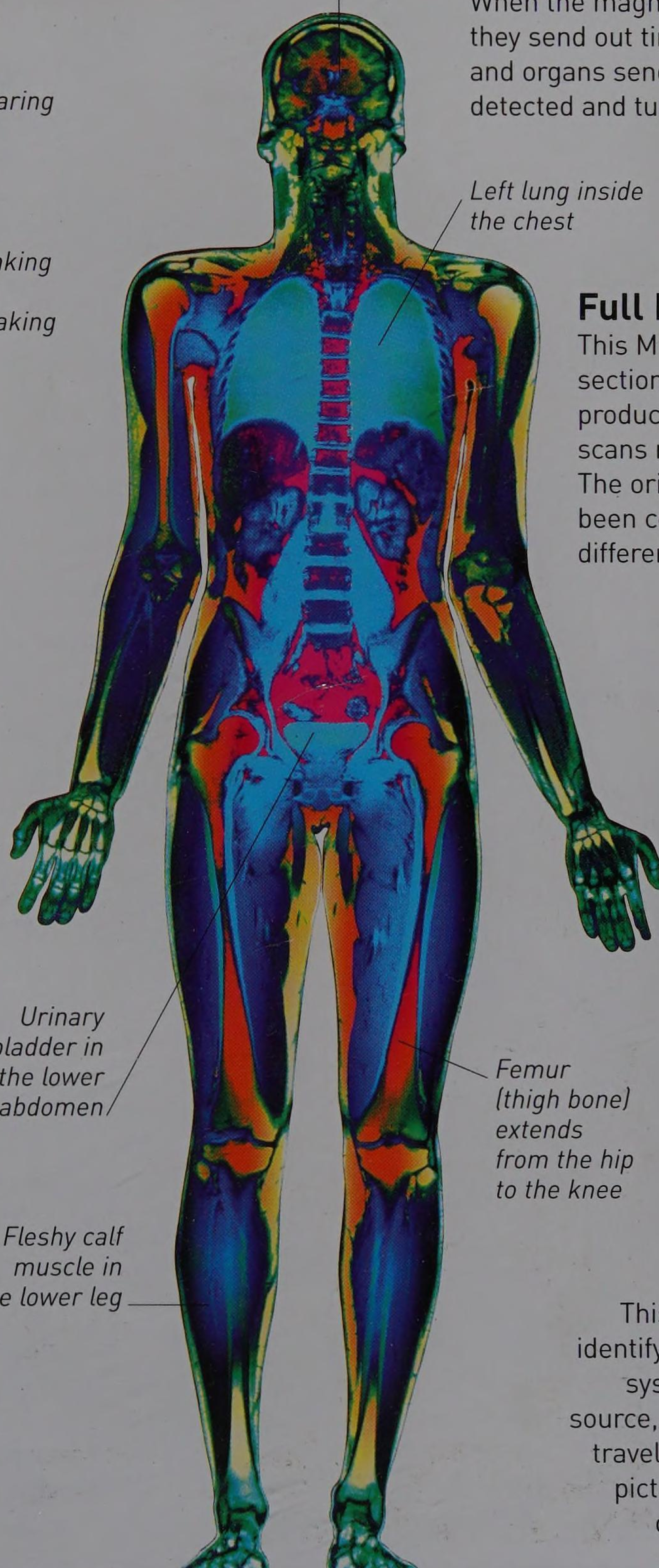
Magnets and radio waves

Inside a magnetic resonance imaging (MRI) scanner, a powerful magnetic field lines up the hydrogen atoms in the patient's body. Bursts of radio waves knock the atoms back into position. When the magnetic field lines the atoms up again, they send out tiny radio signals. Different tissues and organs send out differing signals that are detected and turned into images by a computer.



Brain tissue at work

Positron emission tomography (PET) scans reveal how active specific body tissues are. First, a form of glucose (sugar) is injected into the bloodstream to provide food energy for hard-working tissues. As the tissues consume the glucose, particles are released that can be detected to form an image.

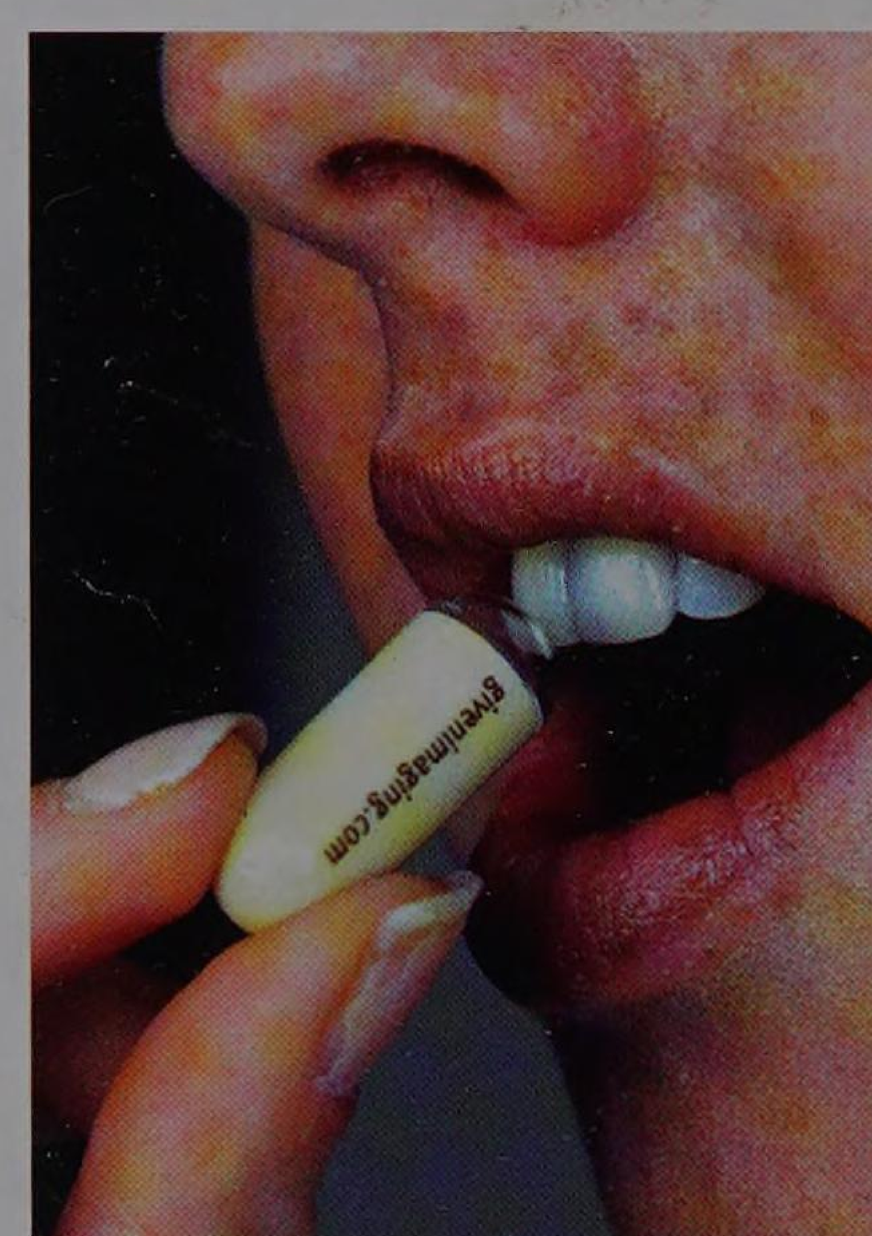


Full body scan

This MRI scan shows a vertical cross-section through a man's body. This is produced by combining many individual scans made along the length of the body. The original black and white image has been colour enhanced to highlight different tissues and organs.

From echo to image

Ultrasound scanning produces moving images such as this fetus inside the womb. High-pitched sound waves are beamed into the body, reflected back by tissues, and converted into images by a computer.



Video pill

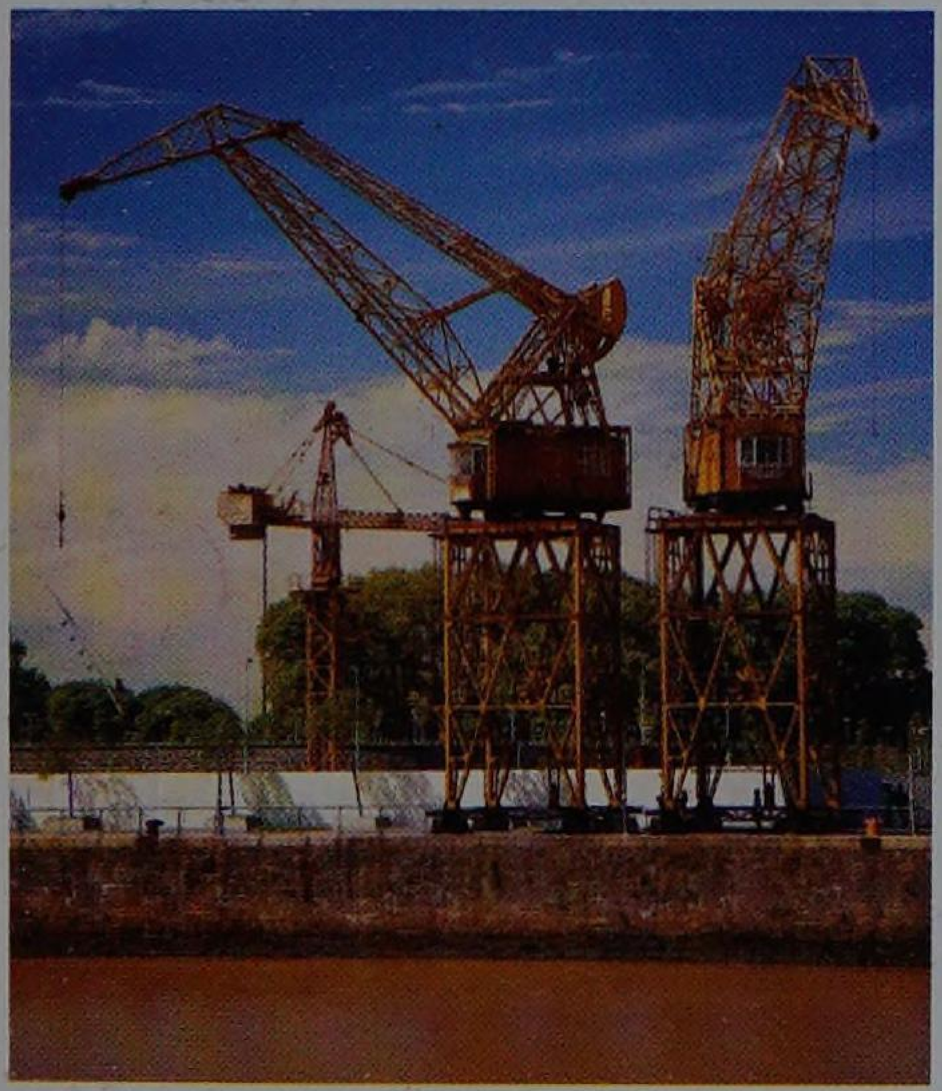
This capsule endoscope can be used to identify damage or disease in the digestive system. It contains a tiny camera, light source, and transmitter. Once swallowed, it travels along the digestive system, taking pictures that are then transmitted to an outside receiver for a doctor to view.

The body's framework

Symbol of death
Skeletons are enduring symbols of danger, disease, death, and destruction – as seen in this 15th-century *Dance of Death* drawing.

The skeleton's 206 bones make up a hard yet flexible framework that serves to support and shape the body. It surrounds and protects organs such as the brain and heart, and stops them being jolted or crushed. Bones also provide anchorage for the muscles that move the skeleton and, therefore, the whole body. Unlike early anatomists, today's scientists can examine bones inside a living body.

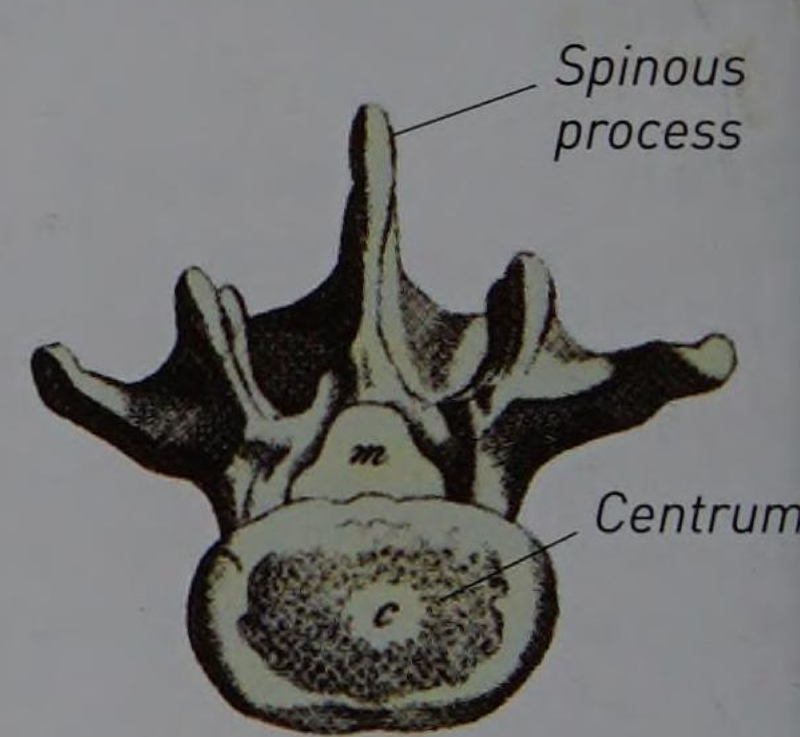
Understanding bones
For centuries, bones were regarded as lifeless supports for the active, softer tissues around them. Gradually, anatomists saw that bones were alive, with their own blood vessels and nerves. Here, the renowned medieval surgeon Guy de Chauliac, author of *Great Surgery* (1363), examines a fracture, or broken bone.



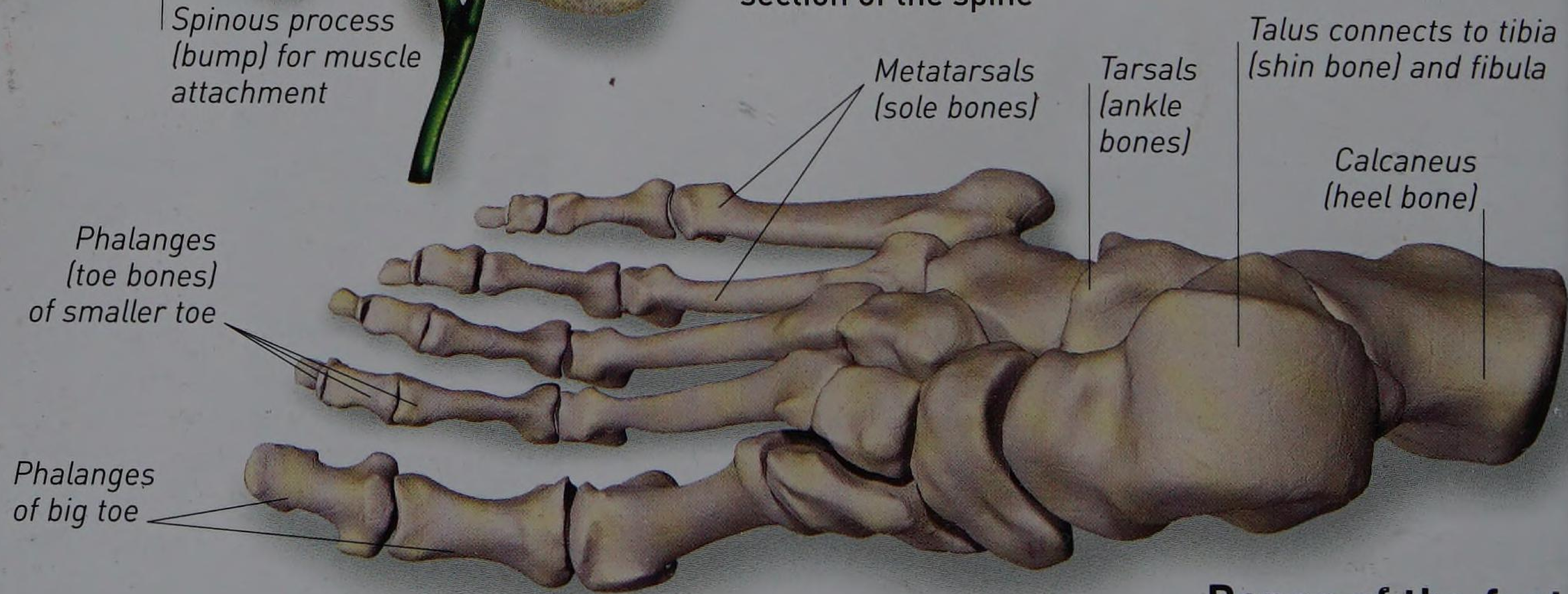
Body mechanics
Many machines copy principles of mechanics shown by the skeleton. For example, each arm has two sets of long bones that can extend the reach of the hand, or fold back on themselves – like these cranes.

Model backbone
The backbone, or spine, is a strong, flexible column of 33 vertebrae that keeps the body upright. Each vertebra has a centrum, which bears the body's weight. A pad of cartilage forms a cushion between one centrum and the next. This allows limited movement between neighbouring vertebrae. All of these tiny movements added together along the length of the backbone enable the body to bend forwards, backwards, side to side, and to twist.

Lumbar (lower back) section of the spine



Early 19th-century drawing of a lumbar vertebra, seen from above



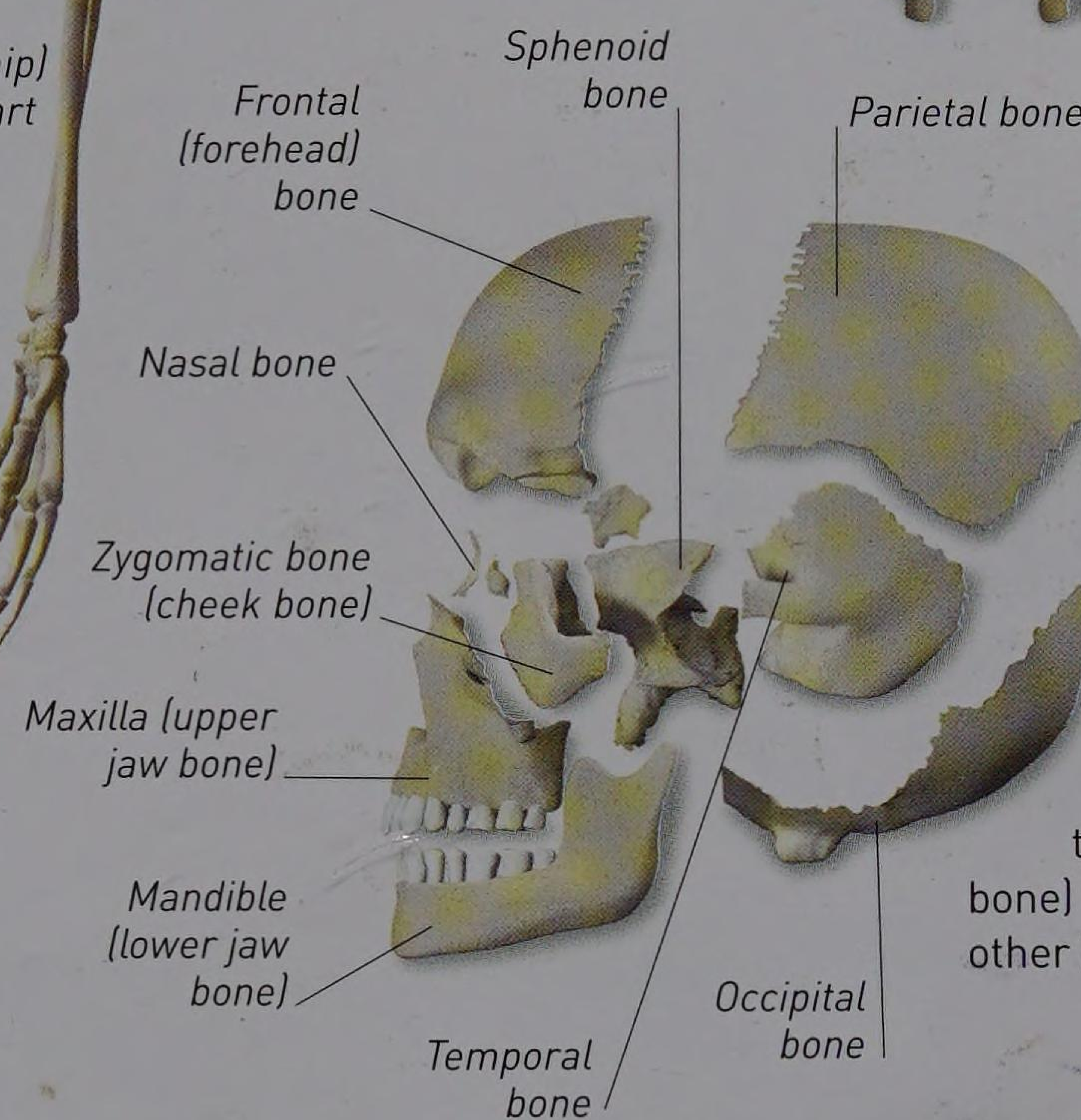
Bones of the foot
The feet bear the whole weight of the body and each one is made up of 26 bones: seven in the ankle, five in the sole, and three in each toe, apart from the big toe which has two.

Human skeleton

The spine, skull, and ribs form the central framework of the skeleton. The skull is supported by the neck vertebrae at the top of the spine. The ribs are attached to the central part of the spine, most of them attaching to the sternum. The arms and legs are connected to the spine by the scapular and clavicle in the pectoral (shoulder) girdle and by the pelvic (hip) girdle.

Front view of the skeleton

Rear and side views of the skeleton

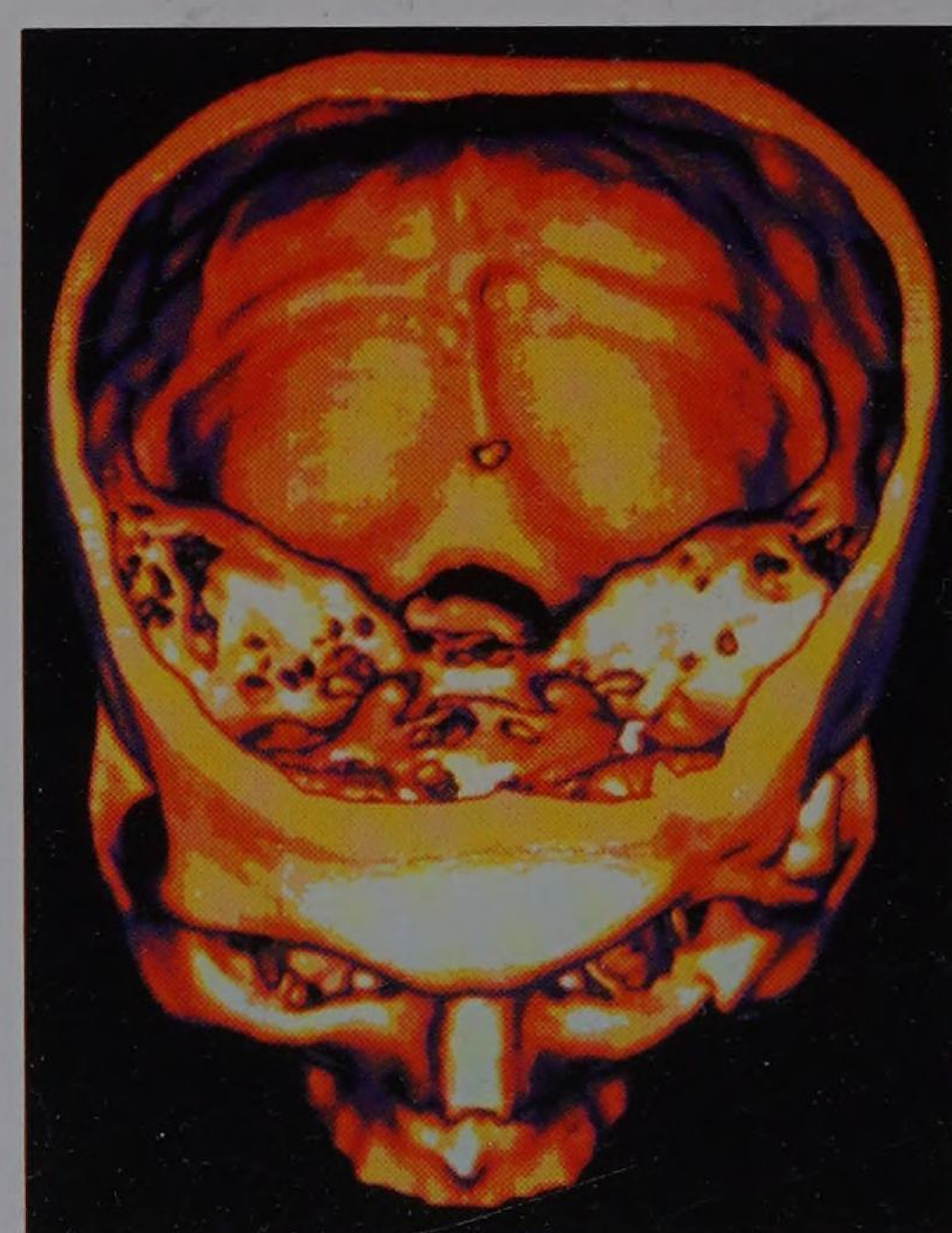


Bones of the skull

The skull is the most complex part of the skeleton. It is made of more than 20 bones, which are simplified here. Eight bones form the domed cranium that contains the brain, and 14 bones shape the face. In an adult skull, the mandible (lower jaw bone) is movable, but all the other bones are fused together.

Inside the skull

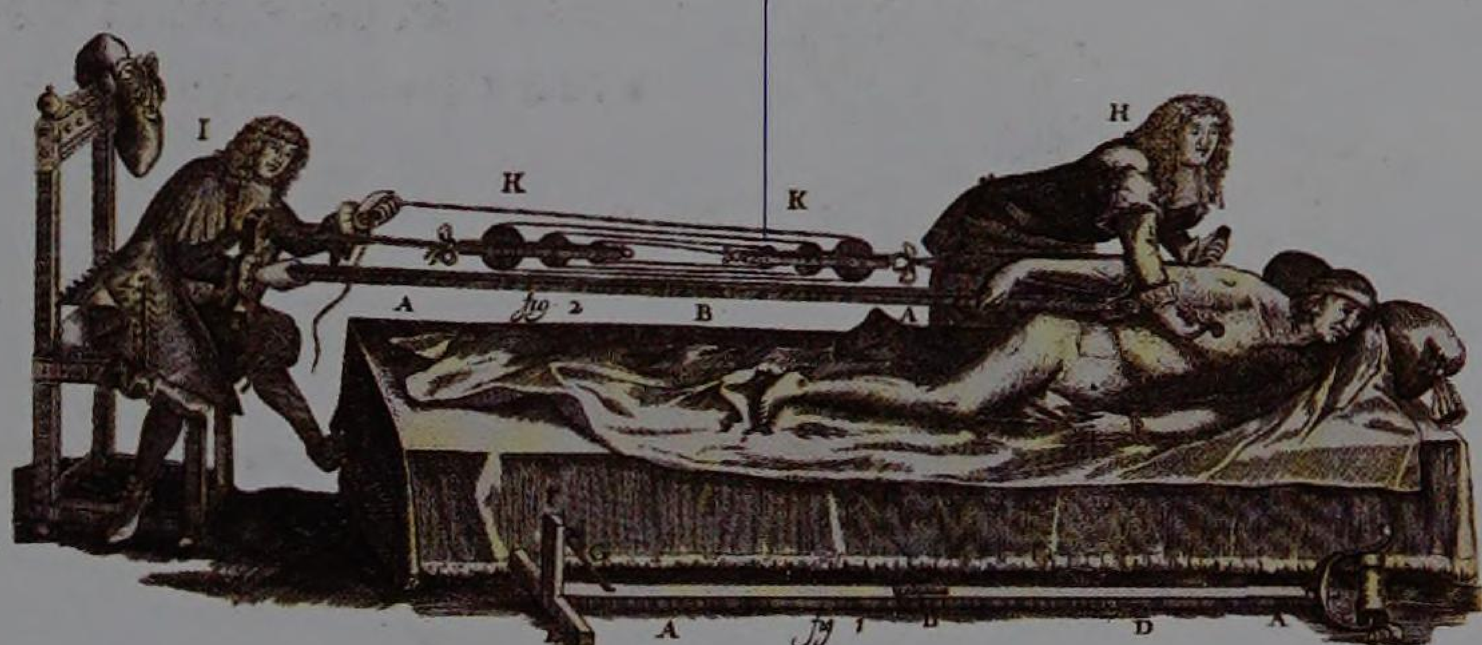
This CT scan shows a 3-D view of the inside of a living skull. This imaging technology is able to remove the top of the cranium, and the brain held within it, to reveal the locked-together skull bones on which the brain sits. At the base of the chamber is the large opening from where the spinal cord makes its downward exit. Also visible are the eye sockets, nasal bones, cheek bones, and the upper jaw.



Inside bones

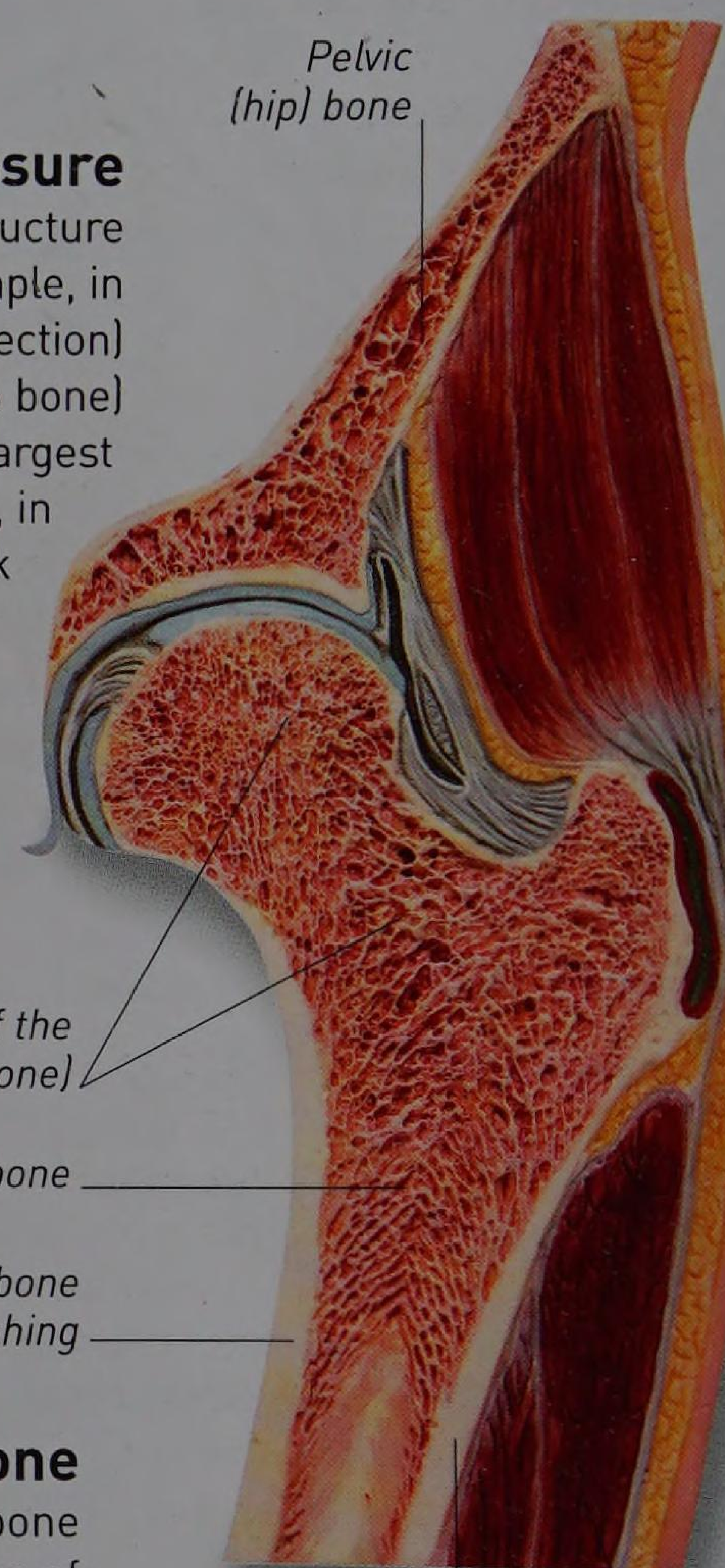
Our bones are living organs with a complex structure of hard bone tissues, blood vessels, and nerves. Bone is as strong as steel, but only one-sixth its weight. Each bone also has a slight springiness that enables it to withstand knocks and jolts, usually without breaking. Tough, dense bony tissue, called compact bone, surrounds light-but-strong spongy bone inside – otherwise the skeleton would be too heavy for the body to move.

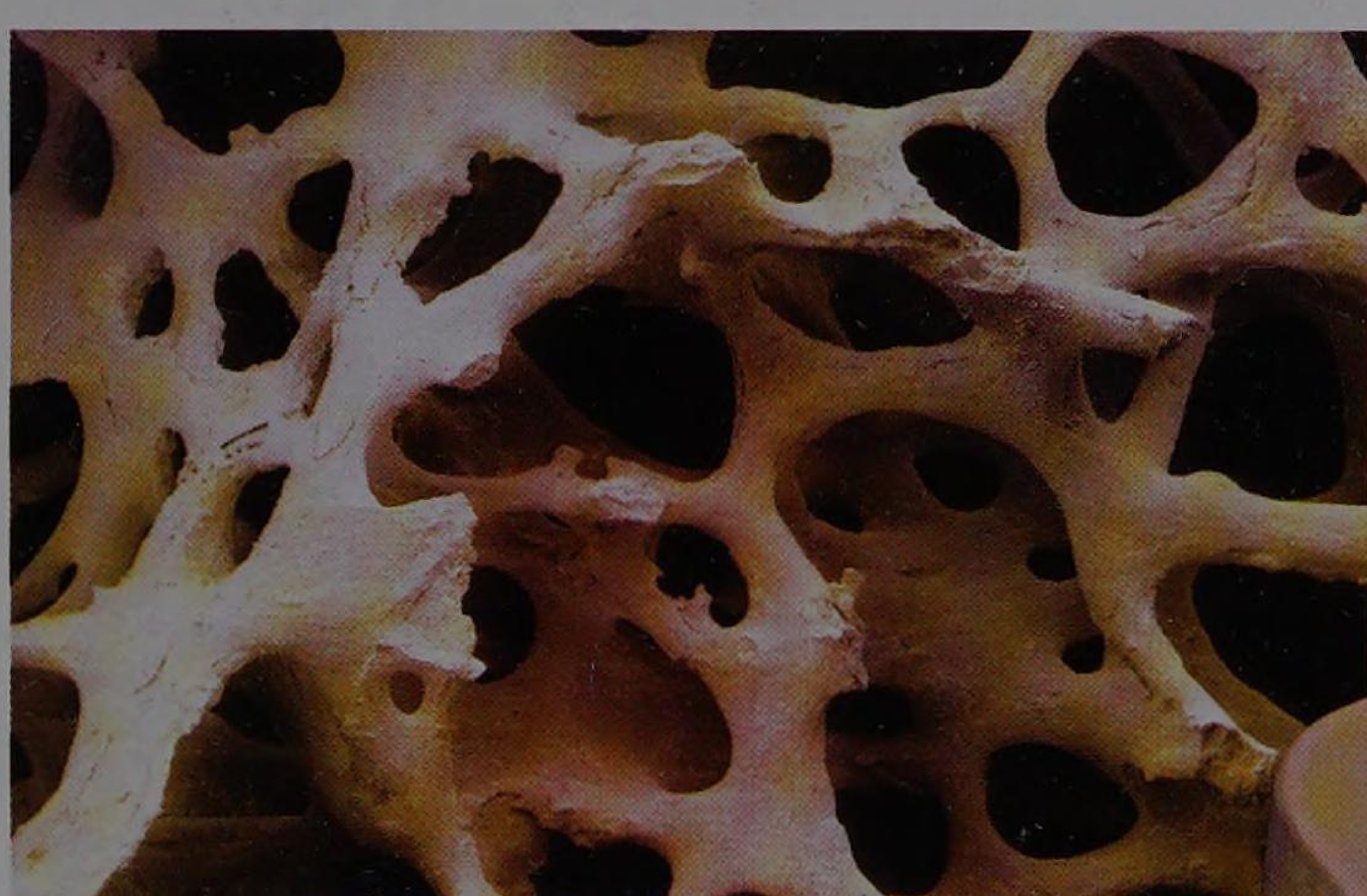
Growing bone
In a young embryo the skeleton forms from bendy cartilage, which then turns into bone over time. This X-ray of a young child's hand shows growing bones (dark blue) and spaces where cartilage will be replaced.



Setting bones
Skeletons of 100,000 years ago show that broken bones were set, or repositioned, to aid healing. Here, 17th-century surgeons are setting a broken arm.

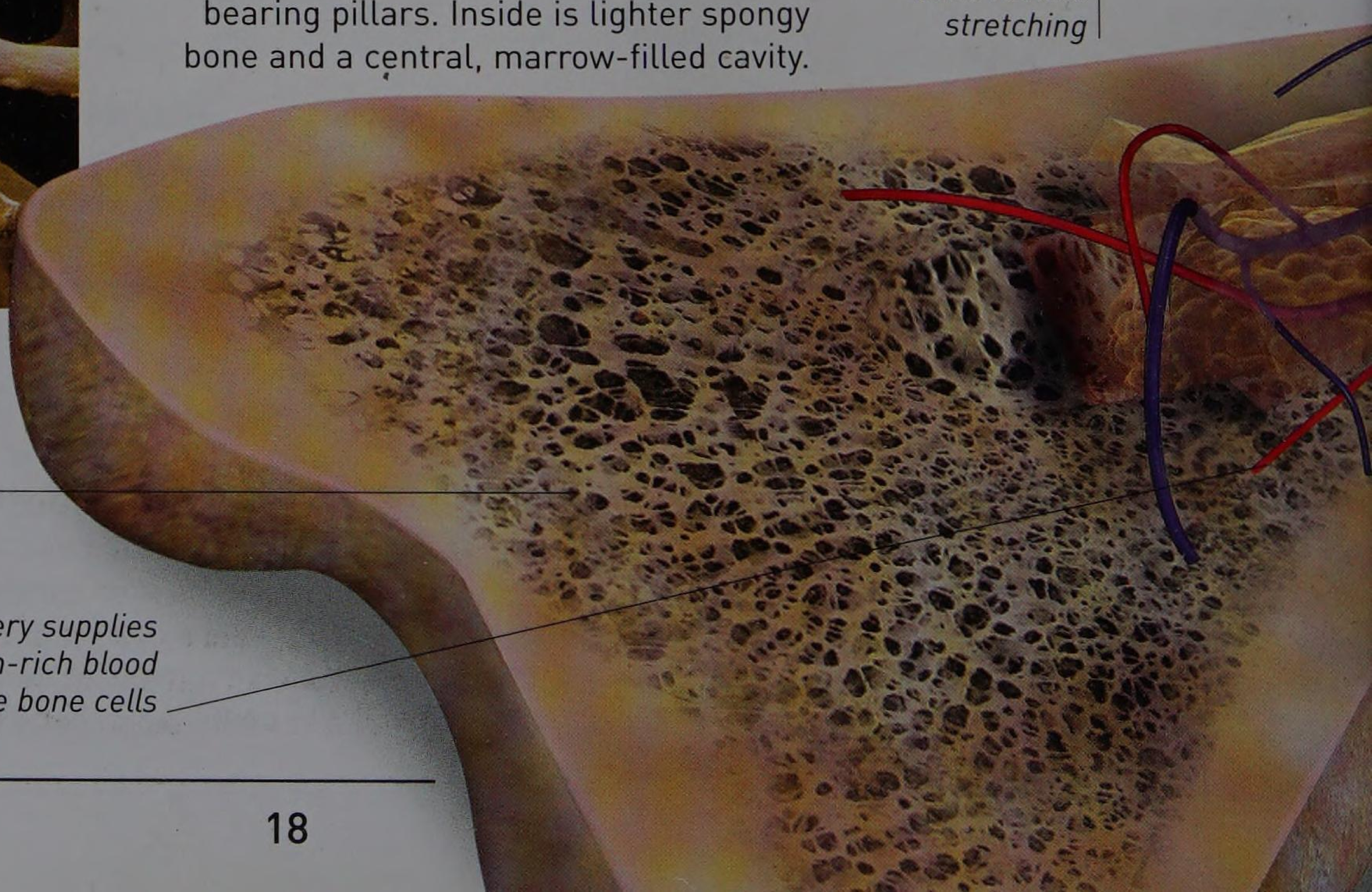
Resisting pressure
When weight is put on a bone, its structure prevents it from bending. For example, in the hip joint (shown here in cross-section) the head and neck of the femur (thigh bone) bear the full weight of the body. The largest area of bone consists of spongy bone, in which the trabeculae, or framework of struts, are lined up to resist downward force. The thin covering of compact bone resists squashing on one side of the femur and stretching on the opposite side.





Spongy bone
This SEM of spongy, or cancellous, bone shows an open framework of struts and spaces, or trabeculae. In living bone these form a structure of great strength and the spaces are filled with bone marrow. Spongy bone is lighter than compact bone, and so reduces the overall weight of a bone.

Inside a long bone
In the cutaway below, compact bone forms the hard outer layer. It is made up of parallel bundles of osteons (see opposite) that run lengthways and act as weight-bearing pillars. Inside is lighter spongy bone and a central, marrow-filled cavity.

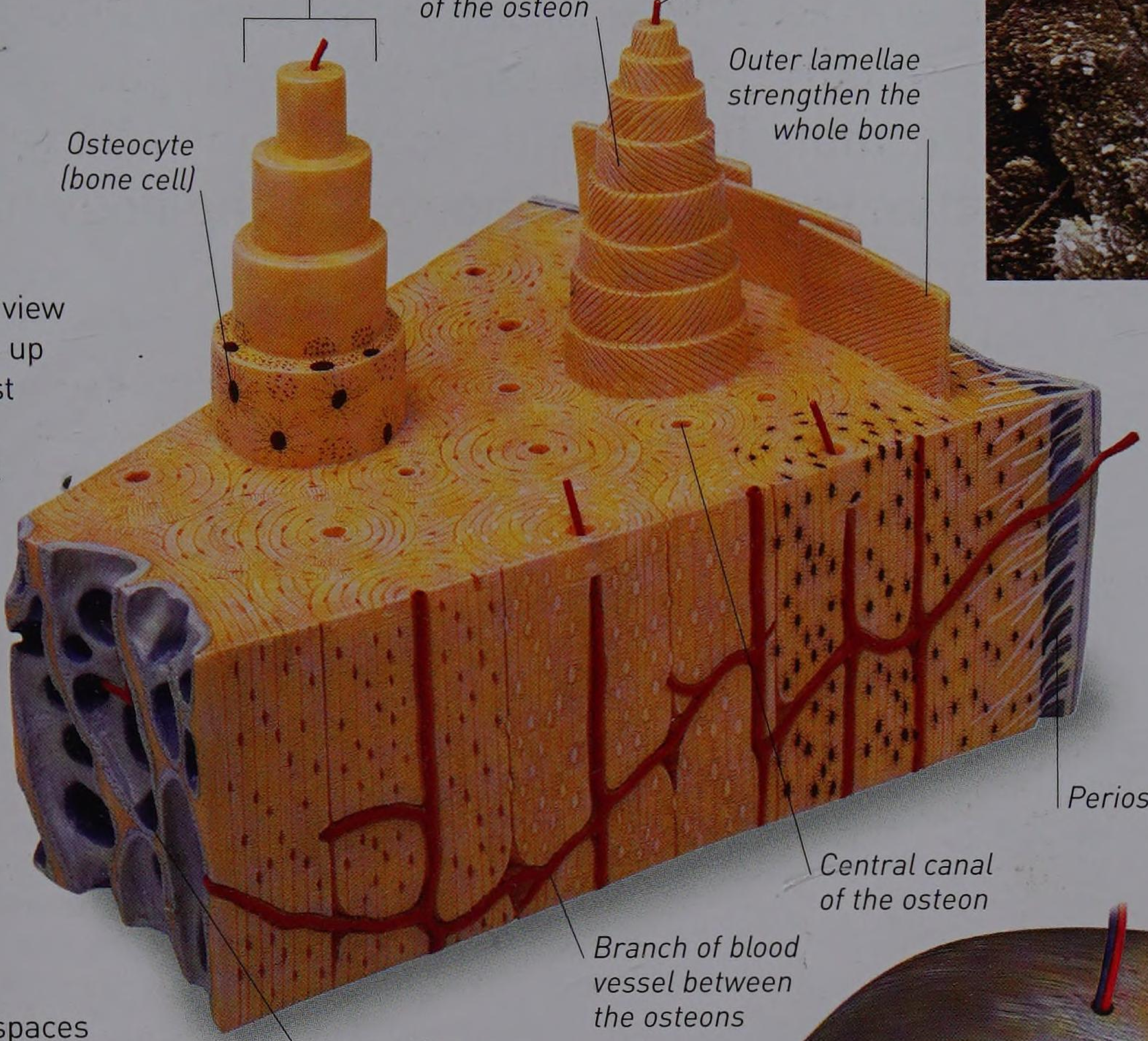


Bone expert

Italy's Giovanni Ingrassias (1510–80) was a founder of osteology, or the study of bones. His research corrected many mistaken ideas about bones. Ingrassias also identified the body's smallest bone, the stapes (stirrup) of the ear, and he described the arrangement of skull bones that form part of the eye socket.

Bone micro-structure

This model shows a microscopic view of a slice of compact bone, made up of layered osteons measuring just 0.25 mm (0.01 in) across. Blood vessels run through their central canal, supplying food and oxygen to the bone cells to maintain the bone framework. This is made of bendy fibres of the protein collagen and hard minerals, mainly calcium phosphate, which make the bone strong but not brittle.

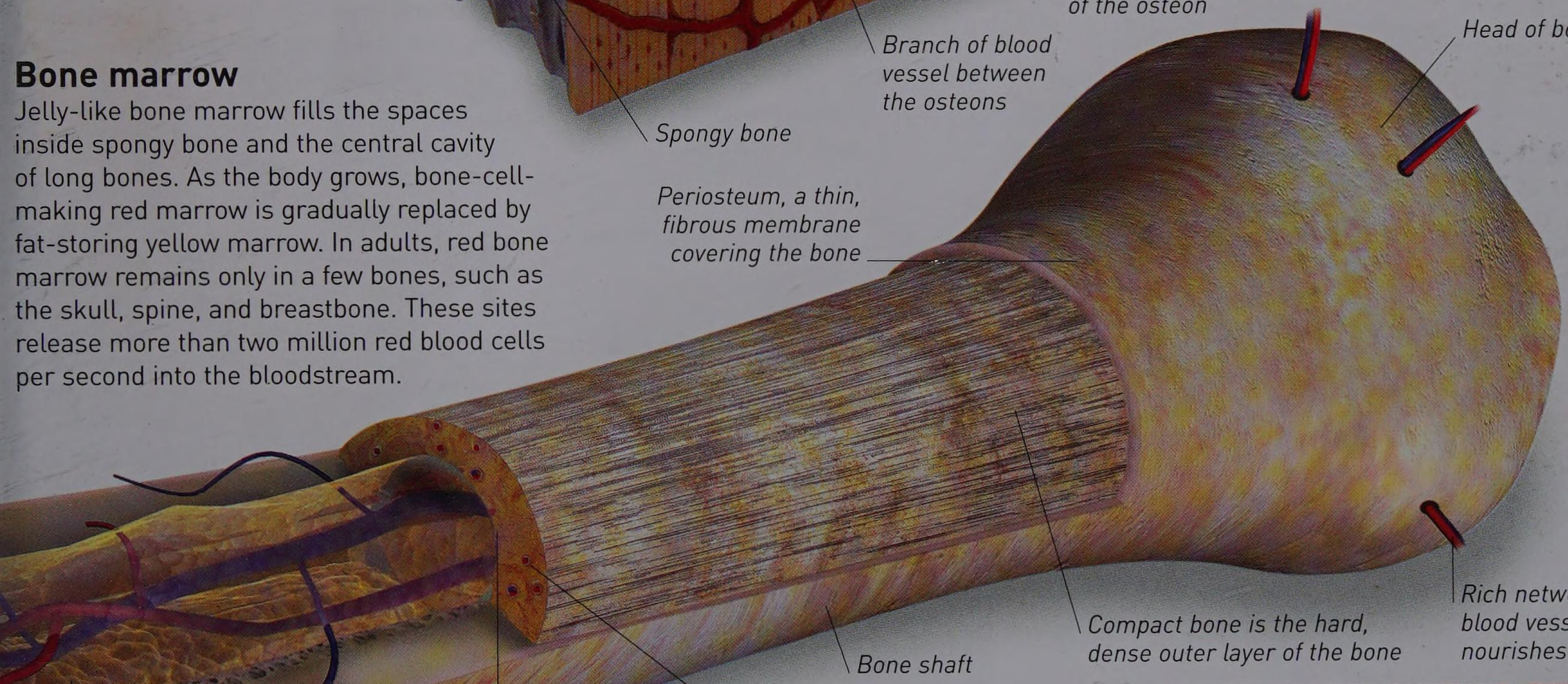


Bone cells

This SEM shows an osteocyte (bone cell) in a lacuna – a tiny space in the framework of minerals and fibres that makes up compact bone. Osteocytes are linked by strand-like extensions of their cell bodies that pass along the narrow canals inside bone.

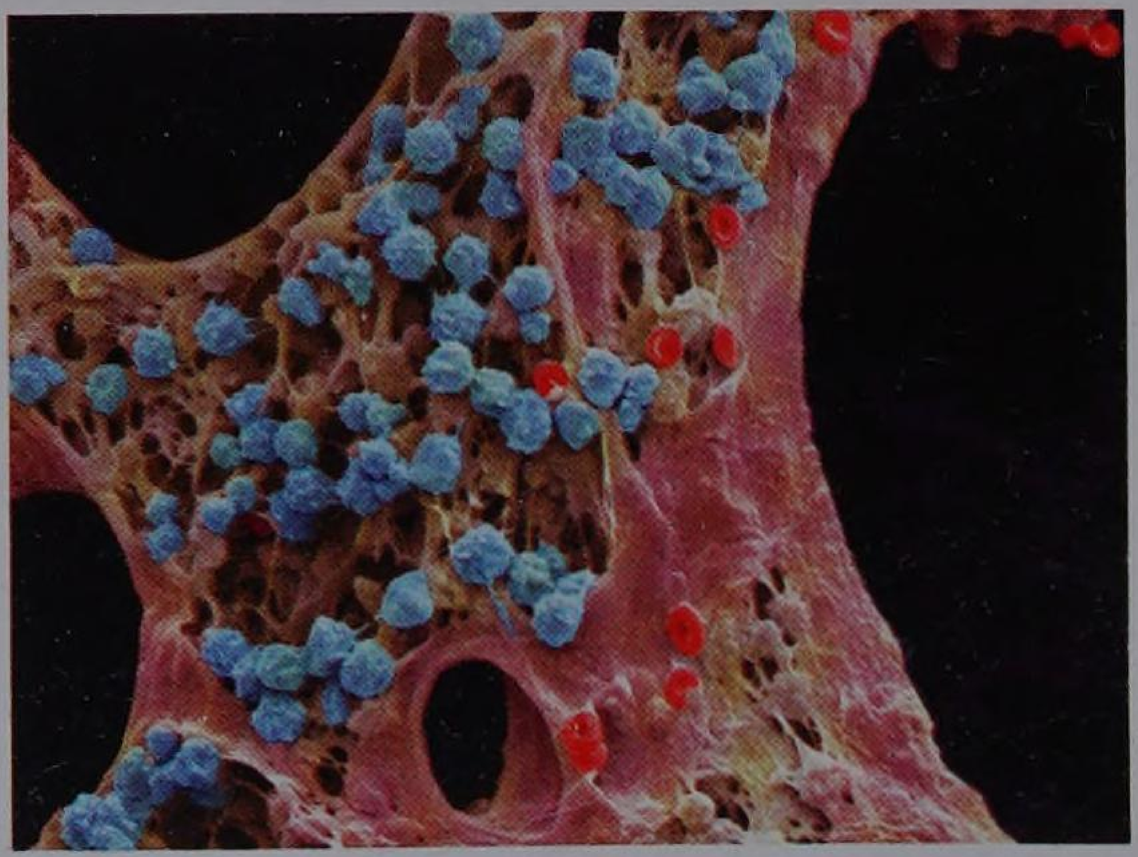
Bone marrow

Jelly-like bone marrow fills the spaces inside spongy bone and the central cavity of long bones. As the body grows, bone-cell-making red marrow is gradually replaced by fat-storing yellow marrow. In adults, red bone marrow remains only in a few bones, such as the skull, spine, and breastbone. These sites release more than two million red blood cells per second into the bloodstream.



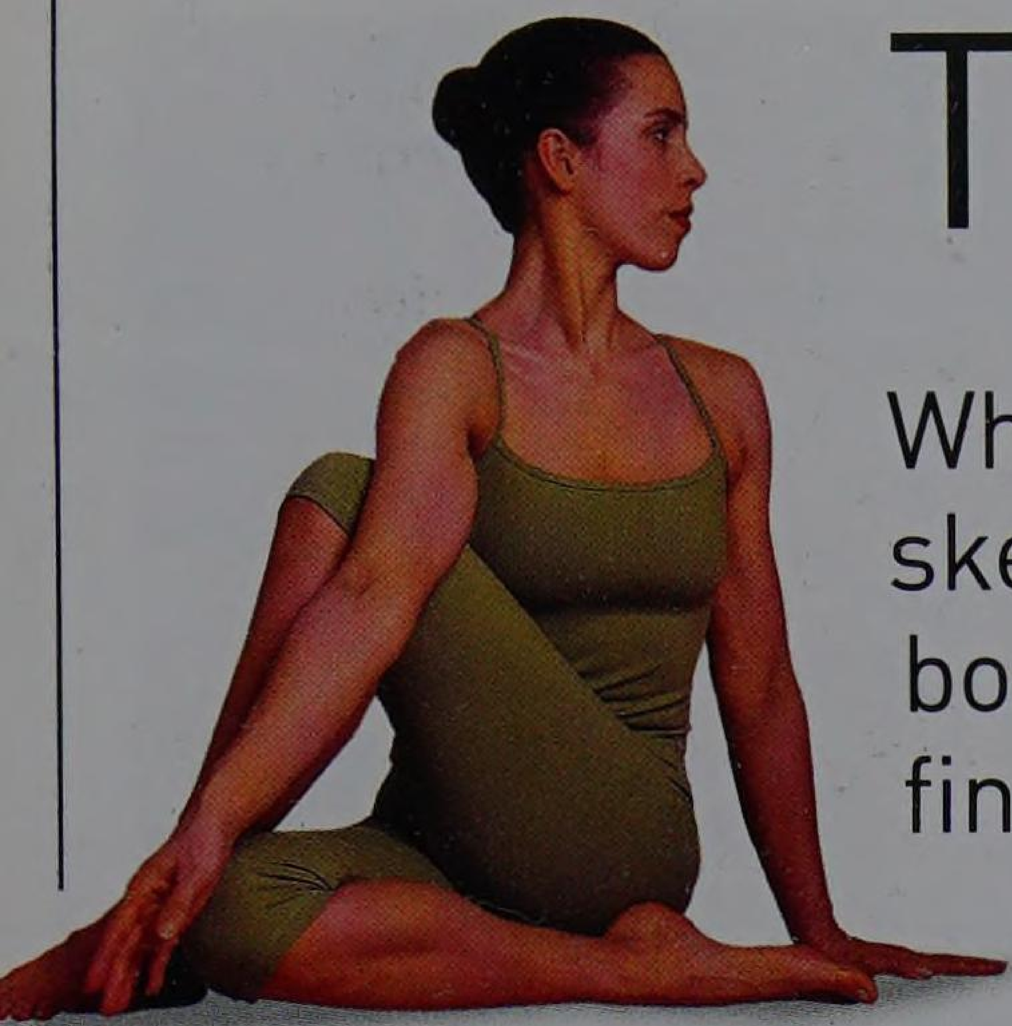
Making new blood cells

This SEM shows red bone marrow, where blood cells are made. Unspecialized stem cells multiply to produce cells that rapidly multiply again to form billions of red blood cells (red) and white blood cells (blue).



The body's joints

Wherever two or more bones meet in the skeleton, they form a joint. Most of the body's 400-plus joints, such as those in our fingers and toes, are synovial, or freely movable. There are several types of movable joint, held together by ligaments, which makes the skeleton incredibly flexible. Without them, it would be rigid.

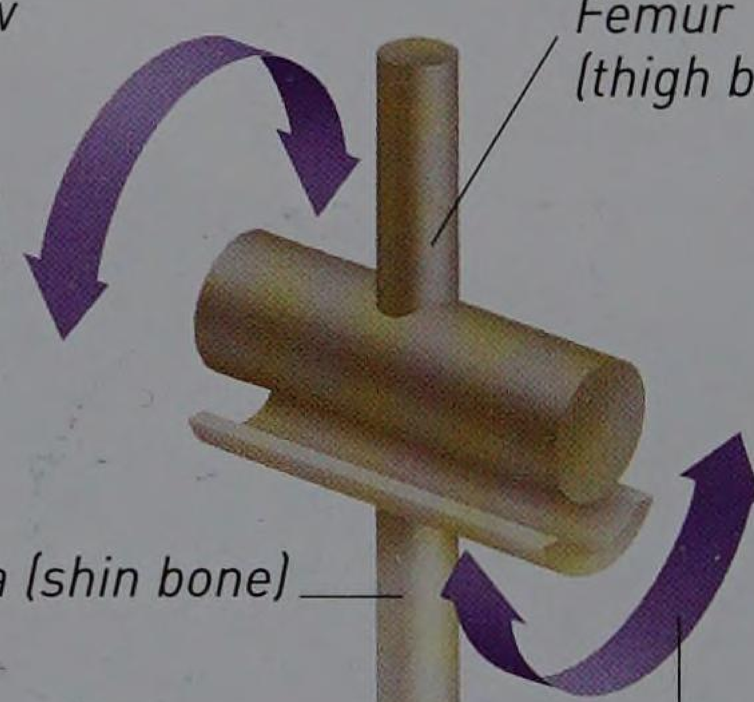


Supple joints
Joints benefit from use, and deteriorate with neglect. Activities such as yoga promote the full range of joint movement and enjoy maximum flexibility.

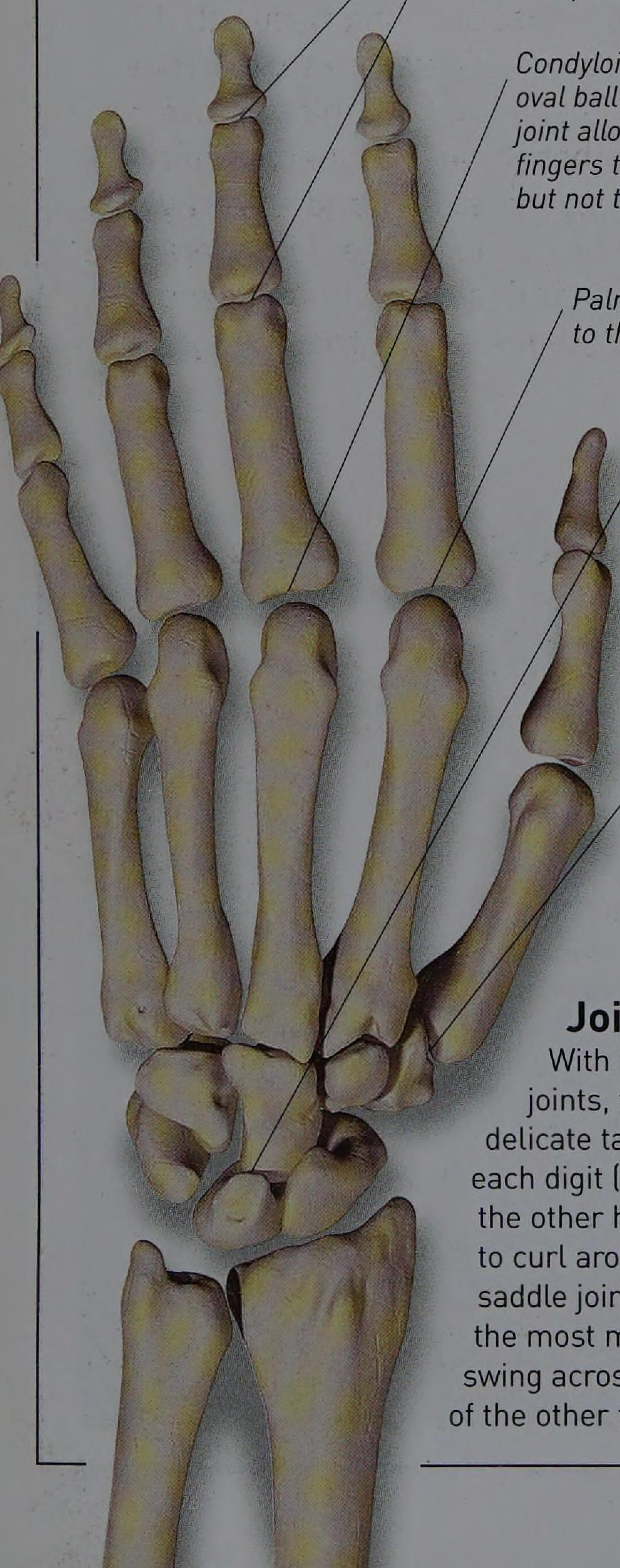
Ball-and-socket joint in the hip

Balls, sockets, and hinges

The hip and knee's movements can be seen whenever someone climbs, walks, dances, or kicks. The hip joint is a ball-and-socket joint. The rounded end of the thigh bone swivels in the cup-shaped socket in the hip bone and permits movement in all directions, including rotation. The knee is a hinge joint and moves mainly in one front-to-back direction.



Hinge joint in the knee



Joints galore

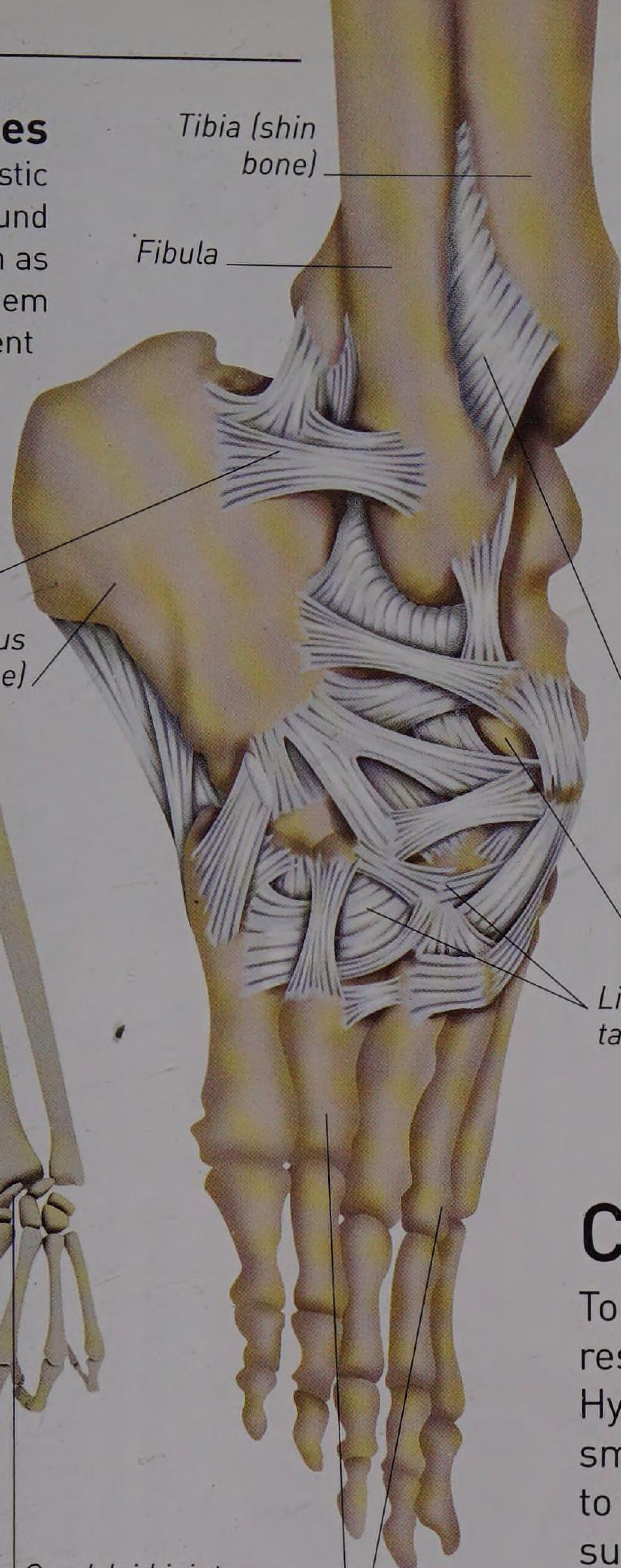
With its 27 bones and 19 movable joints, the hand can perform many delicate tasks. The first knuckle joint of each digit (finger) is condyloid – it and the other hinge joints allow the fingers to curl around and grasp objects. The saddle joint at the base of the thumb – the most mobile digit – allows it to swing across the palm and touch the tips of the other fingers for a precise grip.

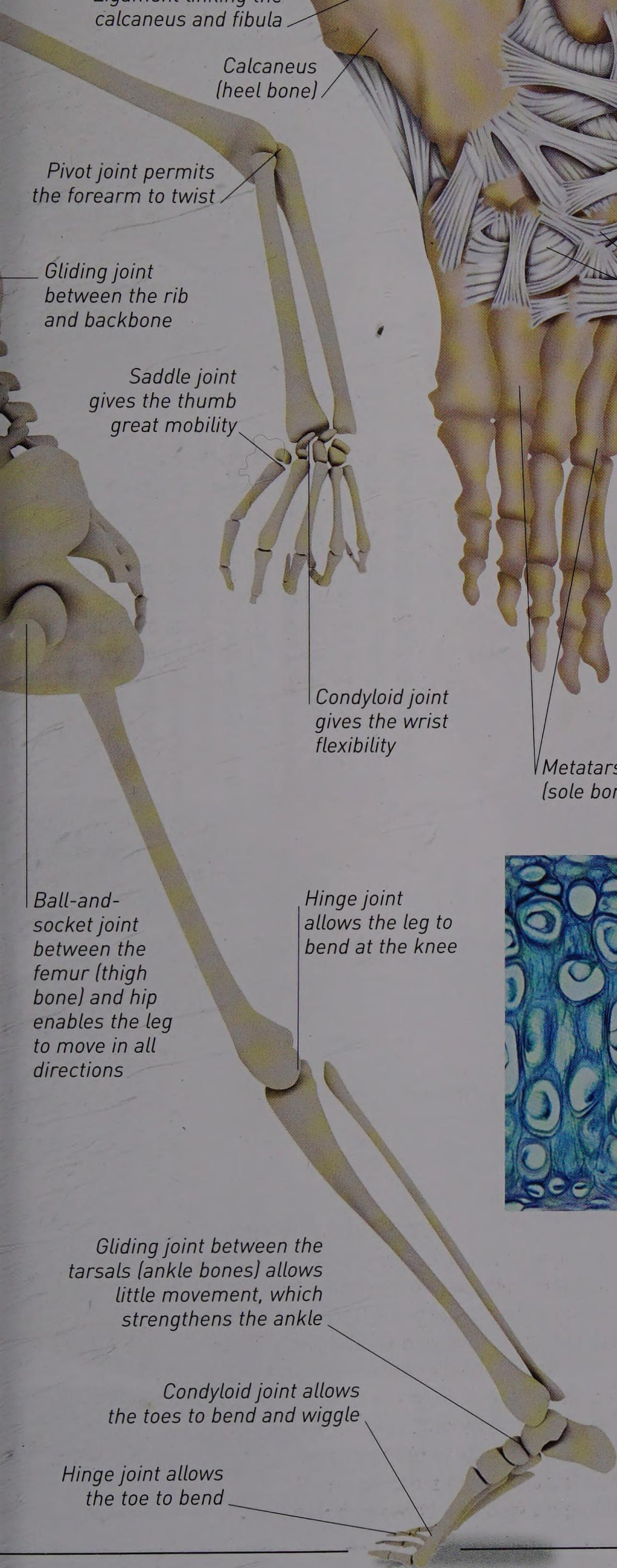
Versatile mover

The skeleton is extremely flexible because it contains many different types of joint, each permitting different ranges of movement. Ball-and-socket, condyloid, and saddle joints allow flexible movements in several directions. Others are more limited. Pivot joints allow movement from side to side, hinge joints back and forth, and gliding joints enable small sliding movements between bones.

Binding the bones

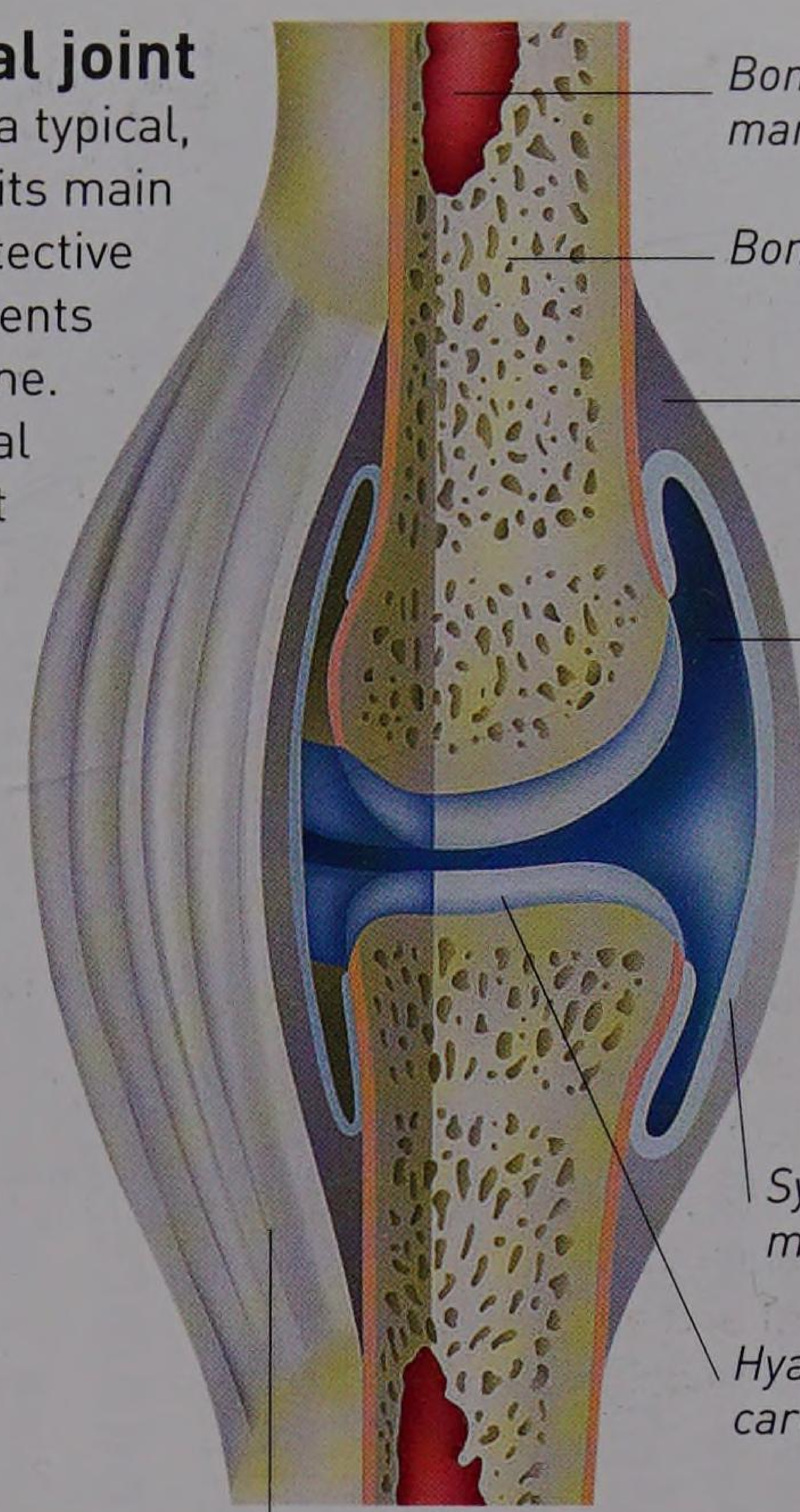
Tough straps of strong, elastic tissue called ligaments surround bone ends in a joint – such as the ankle – and bind them together securely to prevent them from moving excessively.





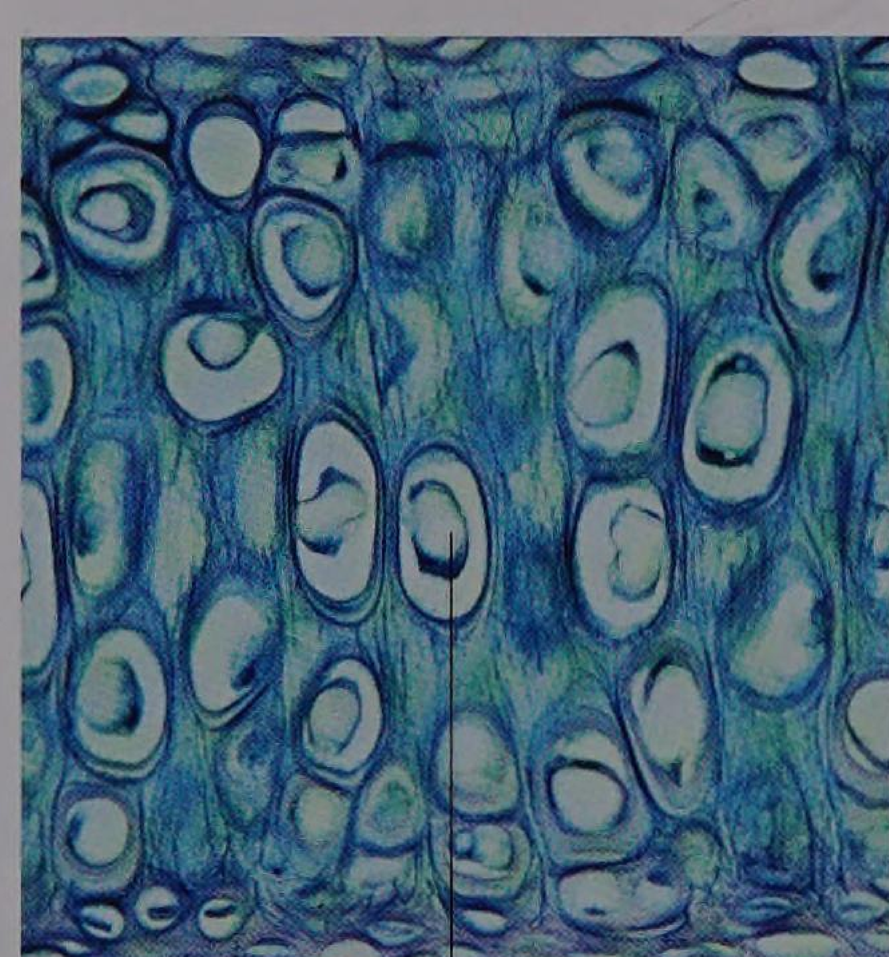
Inside a synovial joint

This view into a typical, movable joint shows its main parts. Inside the protective joint capsule and ligaments is the synovial membrane. This makes synovial fluid, the oil that lubricates the joint. The bone ends are covered by friction-reducing, shiny hyaline cartilage.



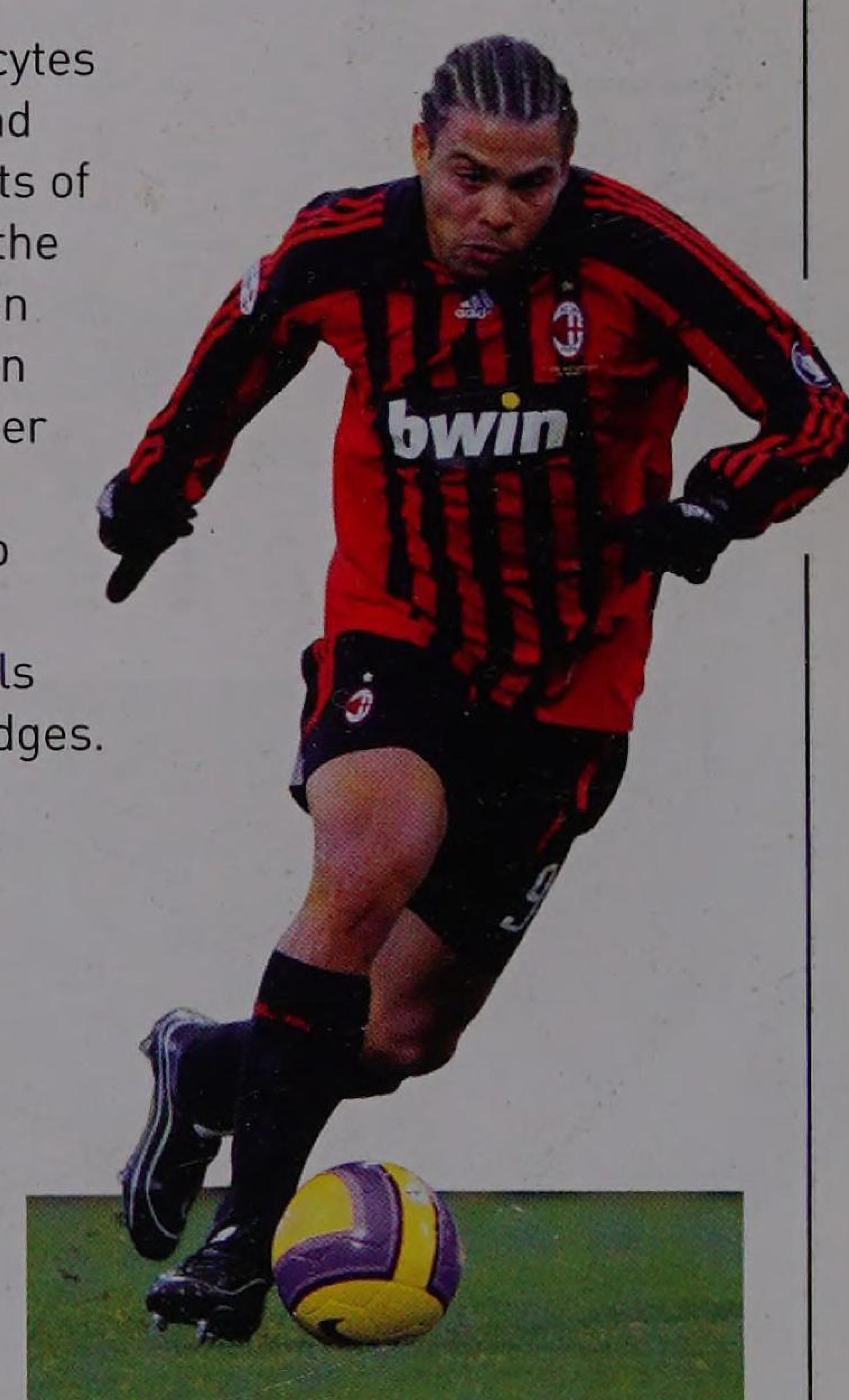
Cartilage

Tough and flexible, cartilage is a supporting tissue that resists pushing and pulling forces. There are three types. Hyaline cartilage covers bone ends to help joints move smoothly. It also, amongst other things, connects the ribs to the sternum. Elastic cartilage is strong and stretchy. It supports the outside of the ear, for example. Fibrocartilage can withstand heavy pressure and is found in the discs between vertebrae in the backbone and in the knee joints.



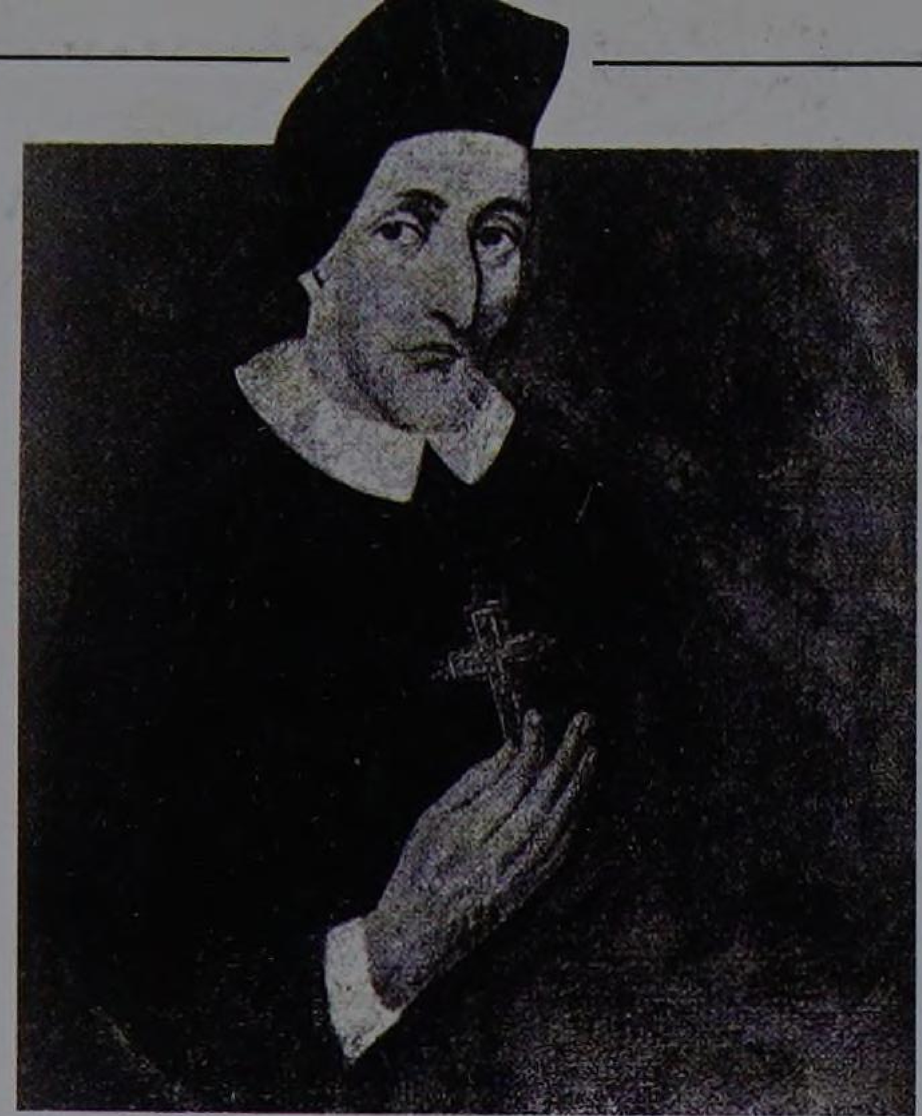
Cartilage cells

Cells called chondrocytes make cartilage around themselves. It consists of two types of fibres – the tough protein collagen and the elastic protein elastin, woven together into a stiff jelly with water. Nutrients seep into cartilage cells from the blood vessels that run around its edges.



Knee trouble

The knee is the body's biggest joint. It is strengthened by ligaments inside the joint, and cushioned from jolts by pads of cartilage called the menisci. Sports such as football involve rapid turns and high kicks, which can cause knee injuries.

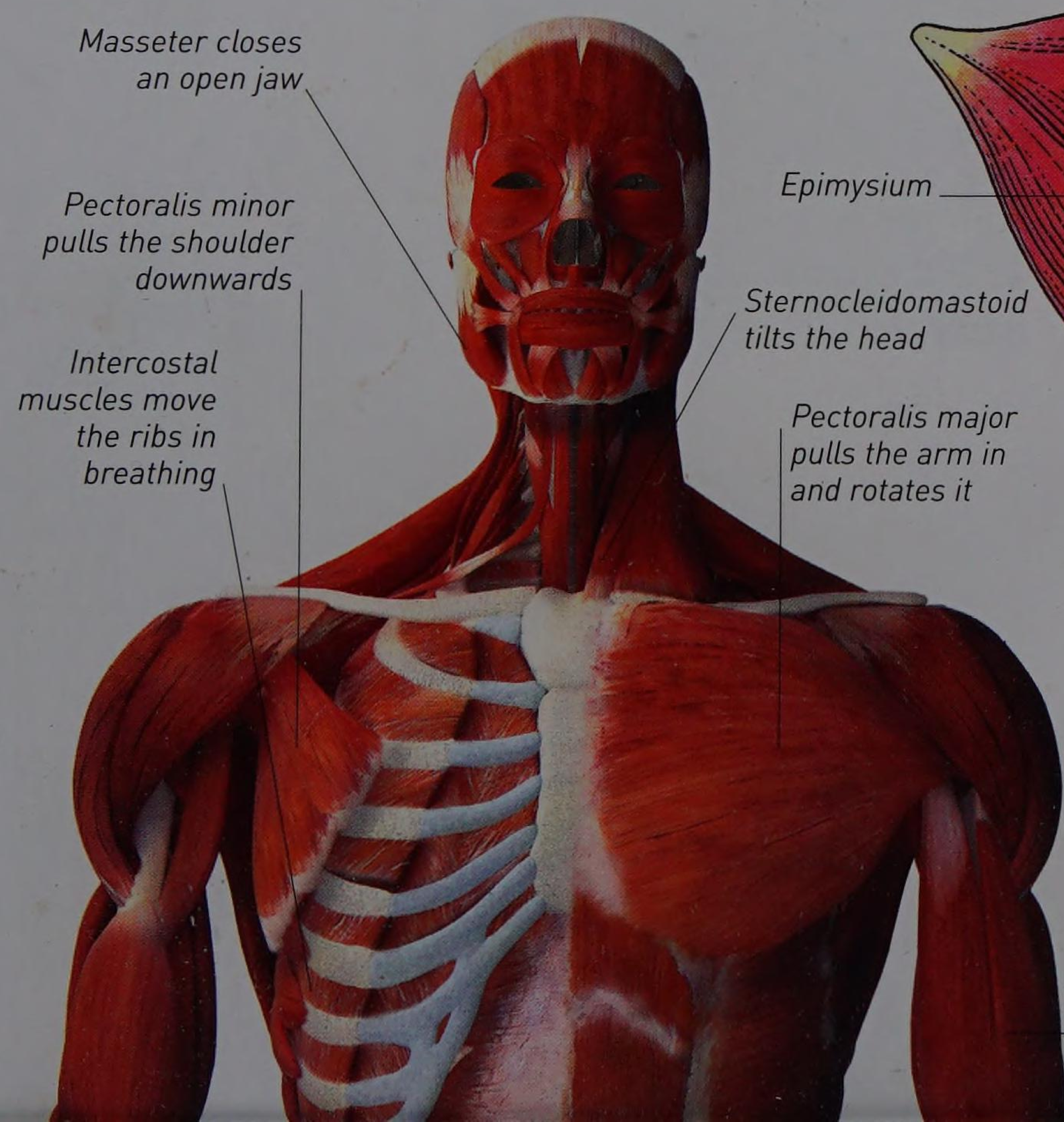


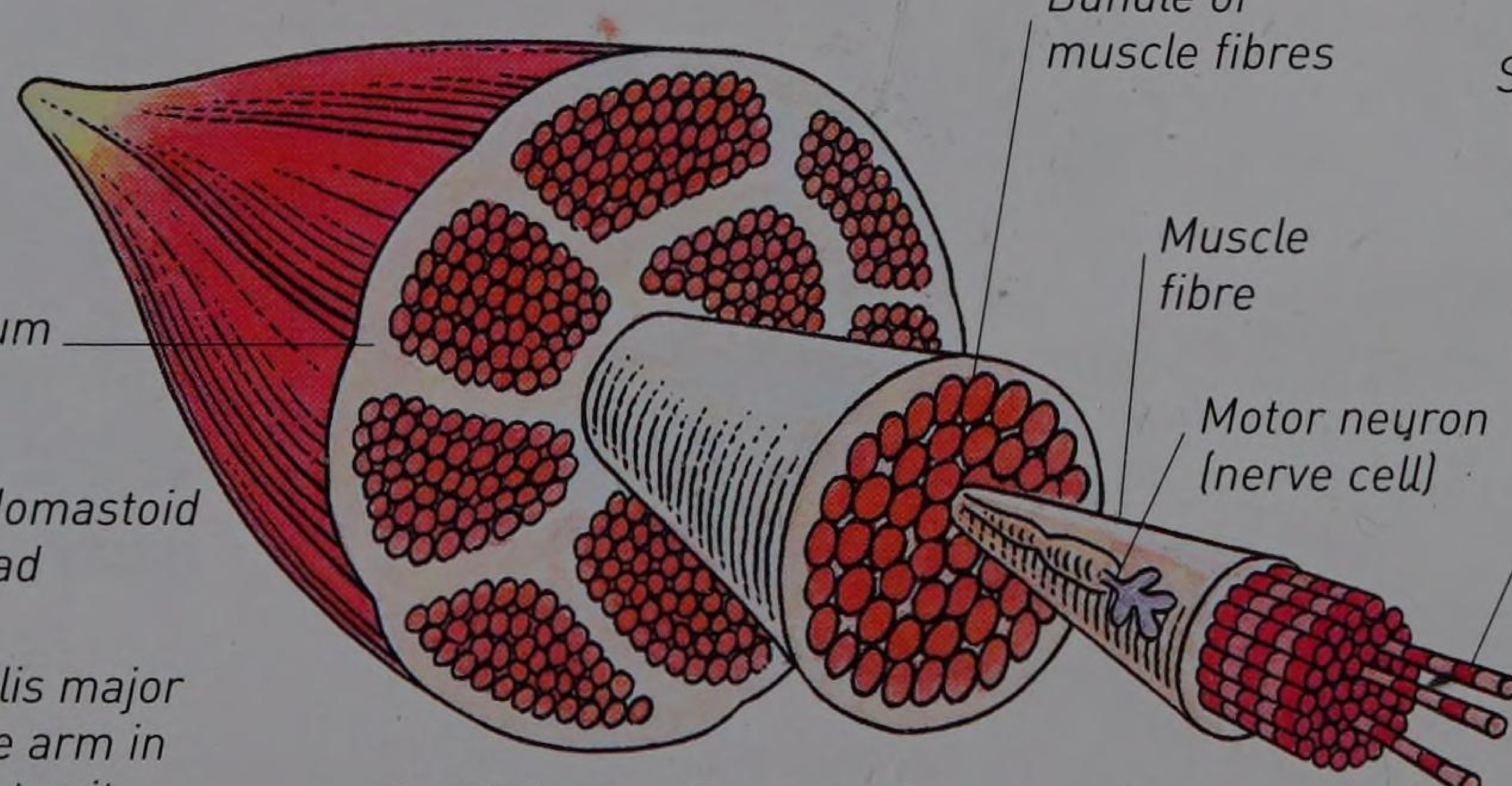
Under the microscope
Danish scientist and bishop Nicholas Steno (1638–86) looked at muscle with a microscope and found that their contraction was due to the combined shortening of the thousands of tiny fibres that make up each muscle.

Muscle power

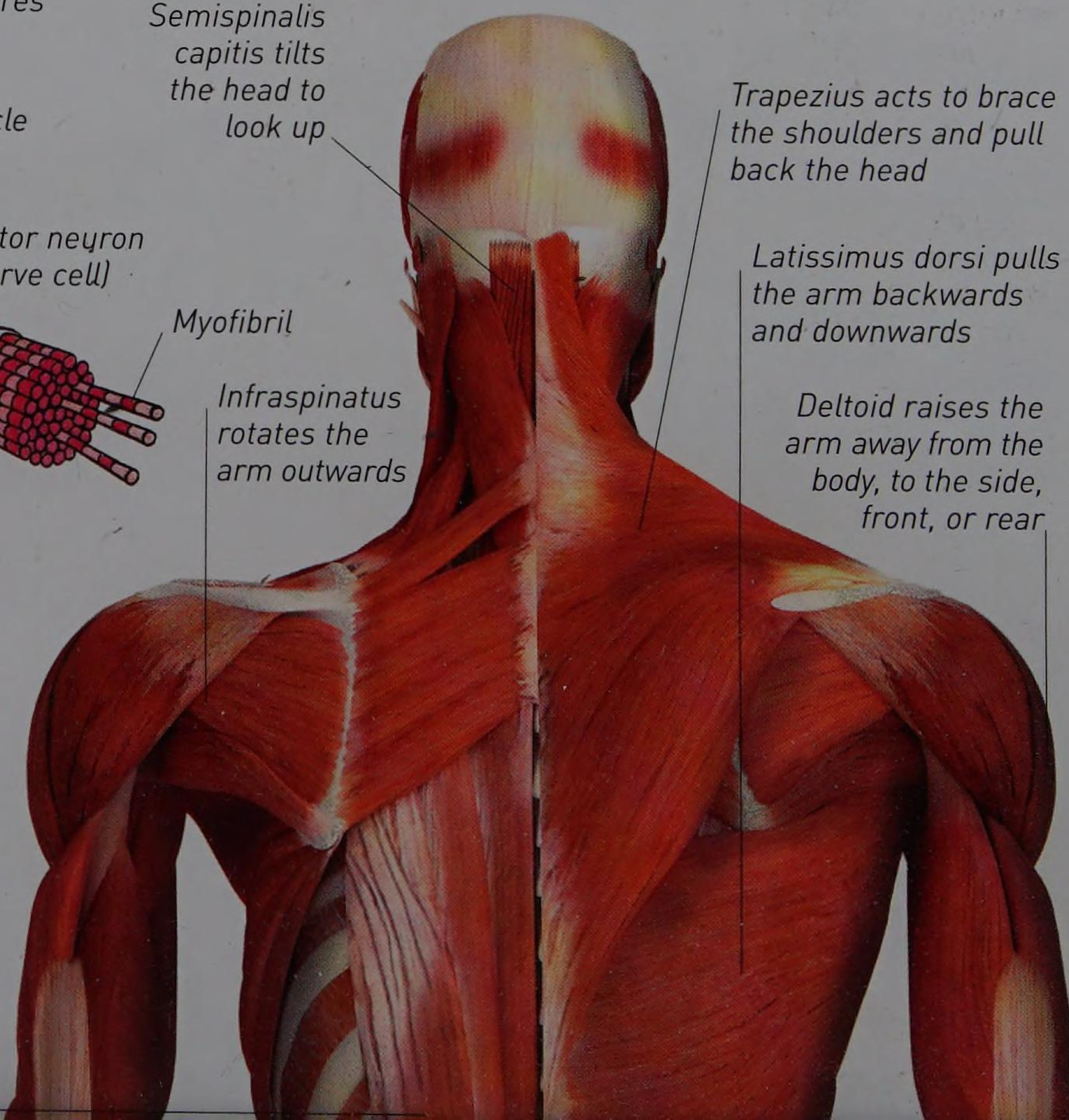
Muscle tissue pulls – and generates movement – by contracting, or getting shorter. Skeletal muscles make up nearly half the body's total mass. They shape the body and, by pulling on bones, hold it upright to maintain posture and allow it to perform a wide range of movements from blinking to running. The two other muscle types are smooth and cardiac muscle. Most muscles have Latin names that describe their location, size, shape, or action.

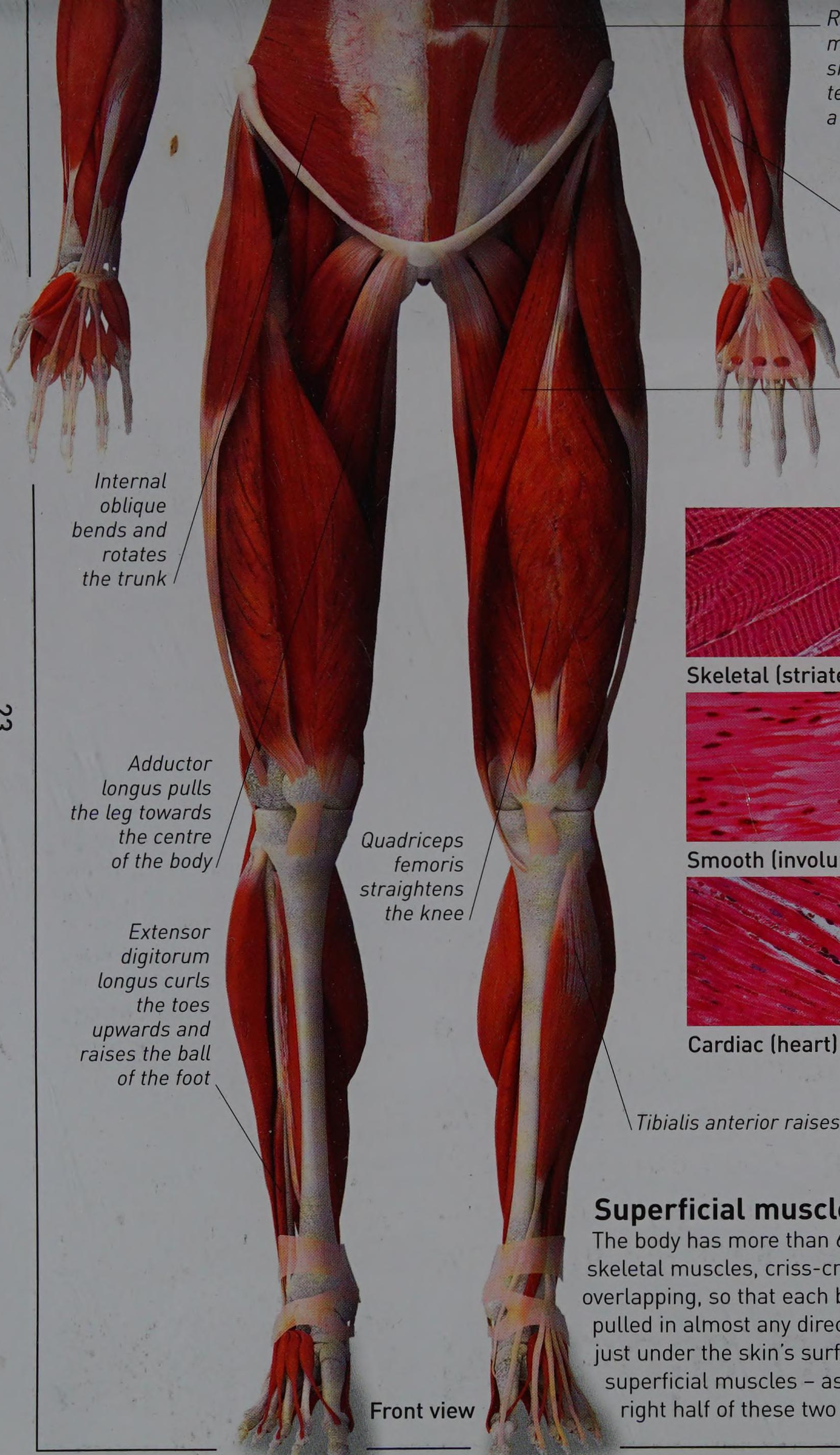
The ultimate book
Italian anatomist Giorgio Baglivi (1668–1707) was the first to note that skeletal muscles differ from the muscles working the intestines and other organs.

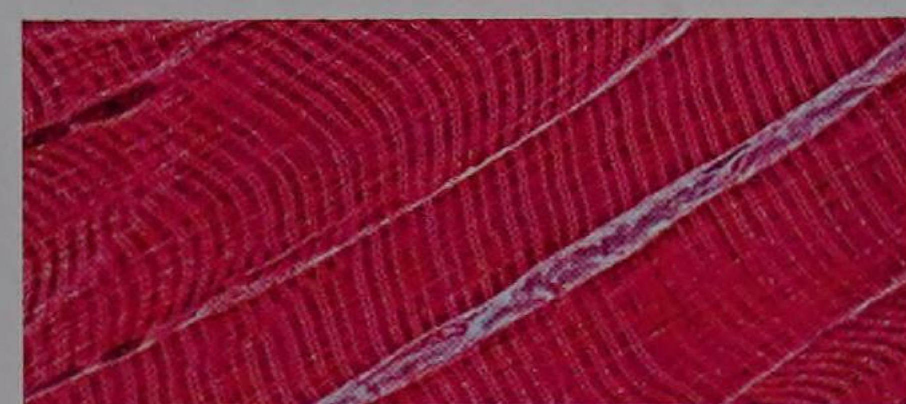




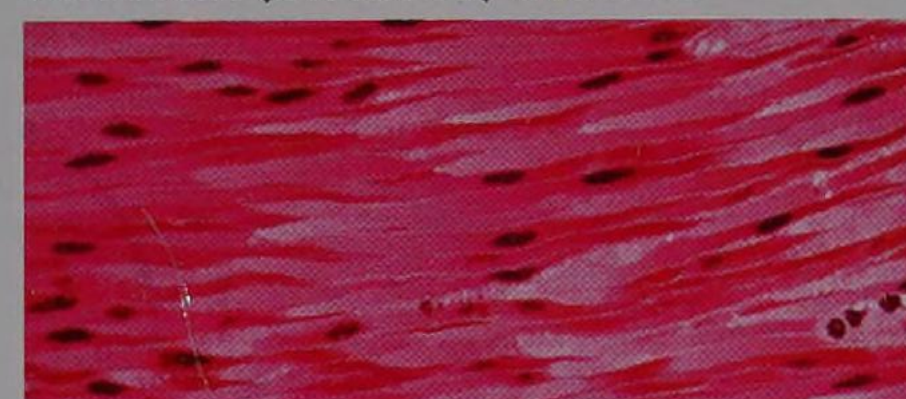
Inside a skeletal muscle
Skeletal muscles are made from long, cylindrical cells called muscle fibres. Each fibre is packed with parallel, rod-like myofibrils that cause contraction. Bundles of fibres are wrapped inside a tough sheath, the epimysium, to form a muscle. Motor neurons (nerve cells) carry signals from the brain, which tell the muscle fibres to contract.







Skeletal (striated) muscle

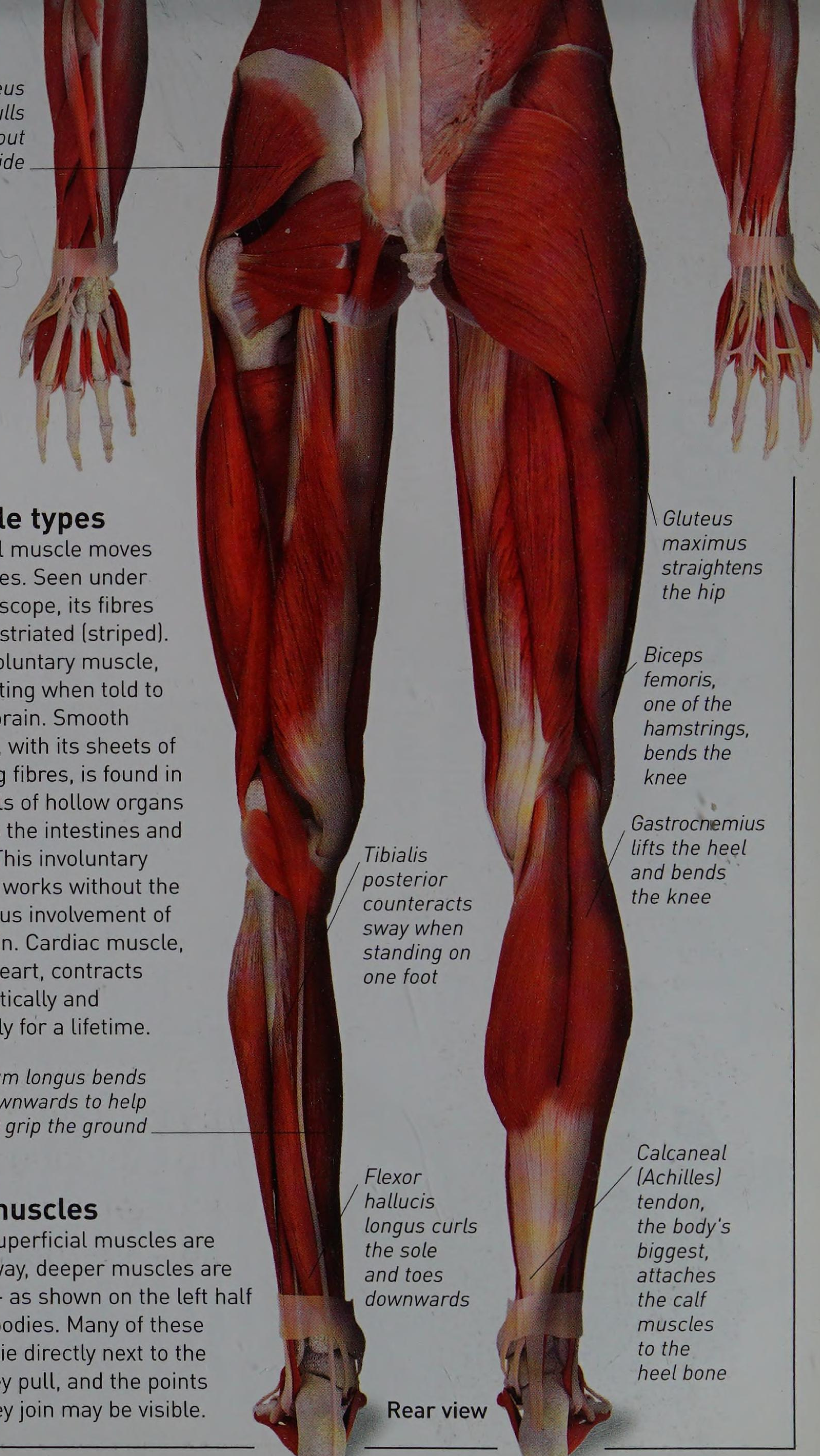


Smooth (involuntary) muscle

Cardiac (heart) muscle

Muscle types

Skeletal muscle moves the bones. Seen under a microscope, its fibres appear striated (striped). It is a voluntary muscle, contracting when told to by the brain. Smooth muscle, with its sheets of tapering fibres, is found in the walls of hollow organs such as the intestines and lungs. This involuntary muscle works without the conscious involvement of the brain. Cardiac muscle, in the heart, contracts automatically and tirelessly for a lifetime.



Superficial muscles

The body has more than 640 skeletal muscles, criss-crossing and overlapping, so that each bone may be pulled in almost any direction. Muscles just under the skin's surface are called superficial muscles – as shown on the right half of these two bodies.

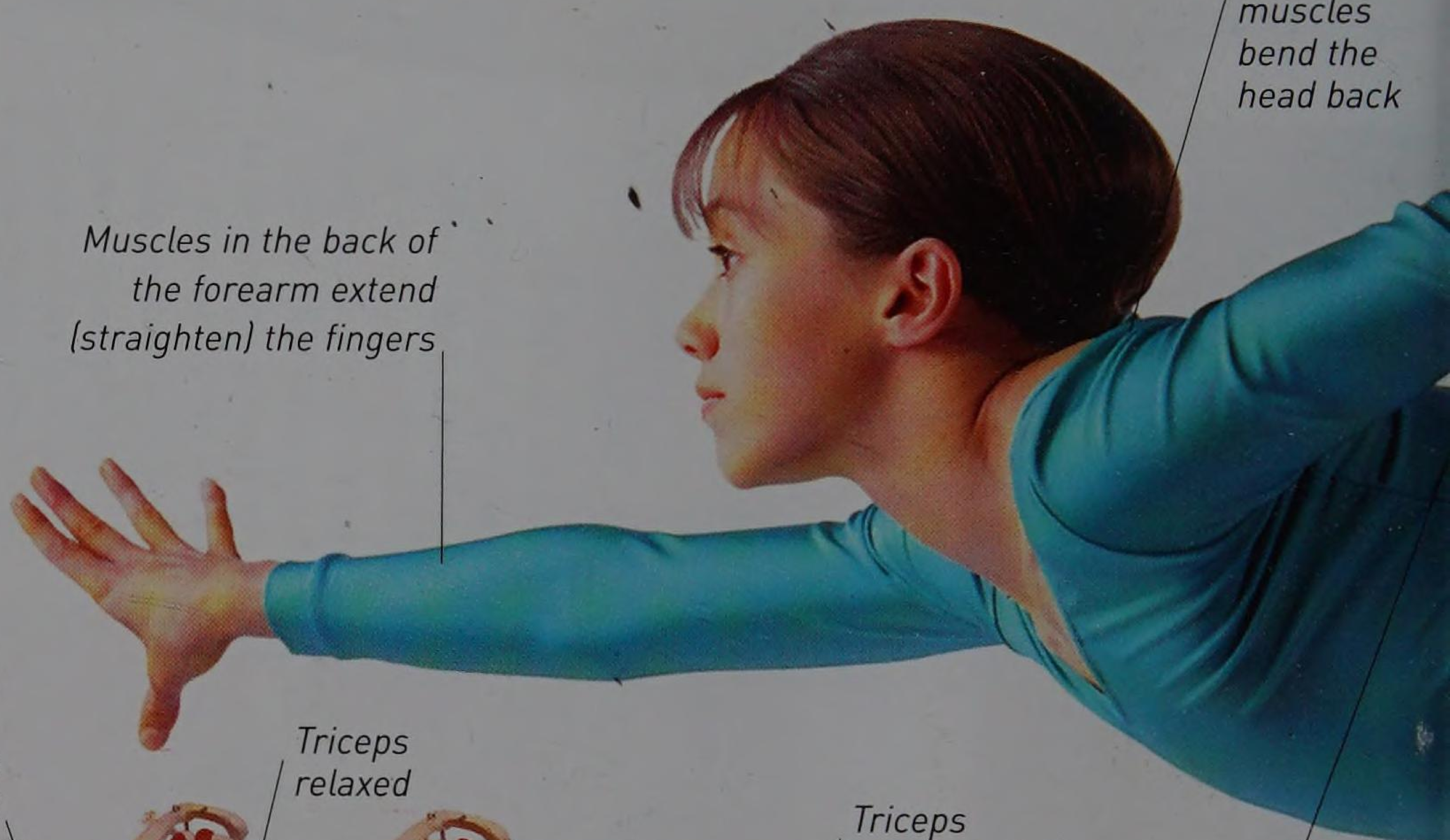
Deep muscles

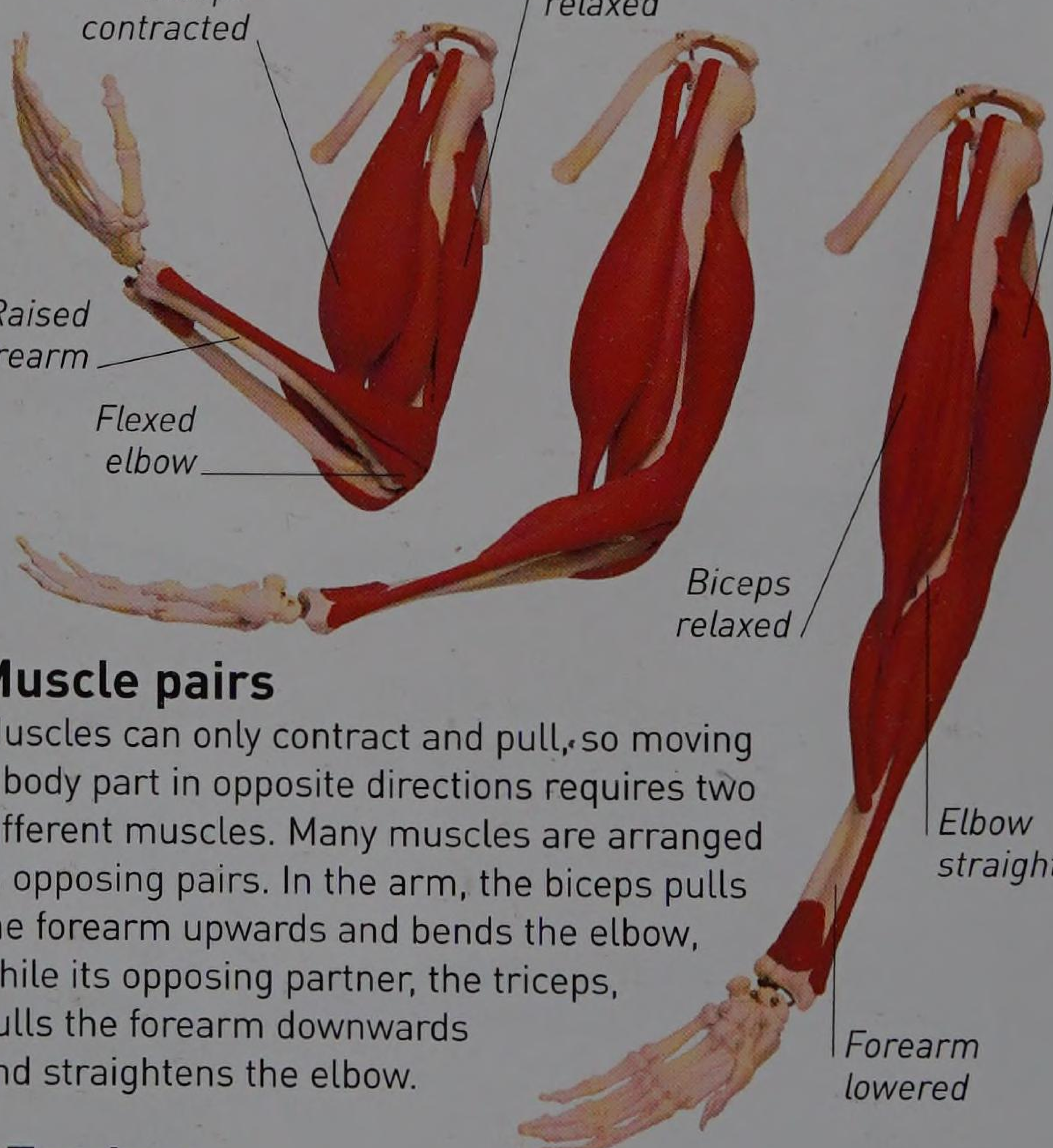
If some superficial muscles are peeled away, deeper muscles are exposed – as shown on the left half of these bodies. Many of these muscles lie directly next to the bones they pull, and the points where they join may be visible.

The moving body

Muscles are attached to bones by tough, fibrous cords called tendons. When muscles contract (get shorter), they pull on a bone. The bone that moves when the muscle contracts is called the insertion and the other bone, which stays still, is called the origin. Muscles can only pull, not push, so moving a body part in different directions requires opposing pairs of muscles.

The three S-words
Muscle fitness can be assessed by strength, stamina, and suppleness. Swimming and dancing promote all three.





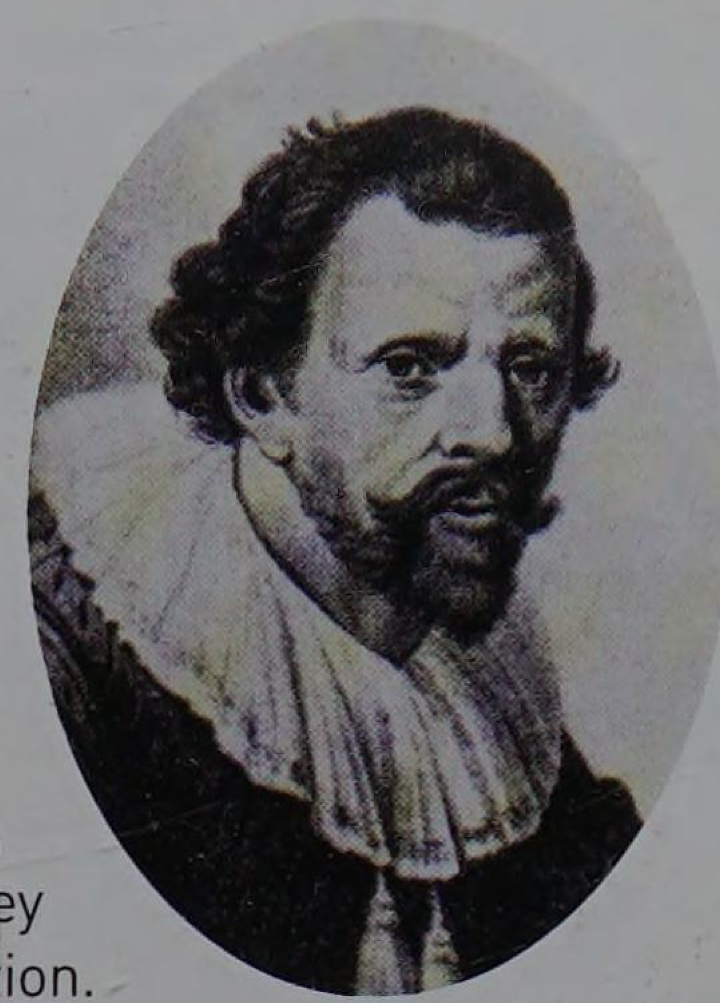
Muscle pairs
Muscles can only contract and pull, so moving a body part in opposite directions requires two different muscles. Many muscles are arranged in opposing pairs. In the arm, the biceps pulls the forearm upwards and bends the elbow, while its opposing partner, the triceps, pulls the forearm downwards and straightens the elbow.

Tendons
Many of the muscles that move the fingers are not in the hand, but in the forearm. They work the fingers by remote control, using long tendons extending from the ends of the muscles to attach to the bones that they move. The tendons run smoothly in slippery tendon sheaths that reduce wear.

Power and precision
With practice, pianists can train their brains to coordinate complex, rhythmic movements in all ten fingers. Muscles work the flexible framework of 27 bones in each hand to play notes ranging from delicate to explosive.

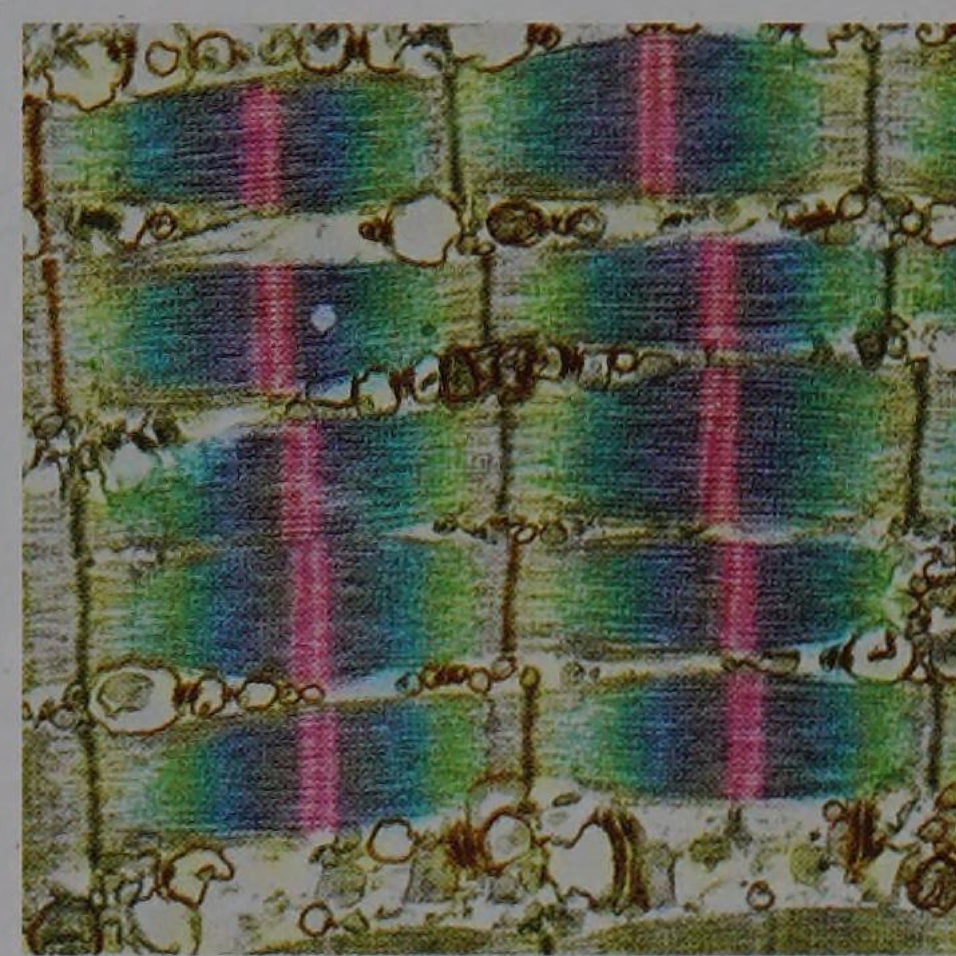
Working together

To perform the pose below, areas of the brain that control movement and balance send out nerve signals to instruct specific skeletal muscles when to contract and by how much. Muscles in the hands, arms, torso, and legs work together to put the gymnast in this position. Signals from the muscles and tendons also feed back to the brain so that minor adjustments maintain her balance.



Old theories

Dutch physician Jan Swammerdam (1637–90) disproved ideas that a vital spirit passed along nerves and inflated muscles to make them contract. He showed that muscles altered in shape, but not in volume (the space they take up) during contraction.

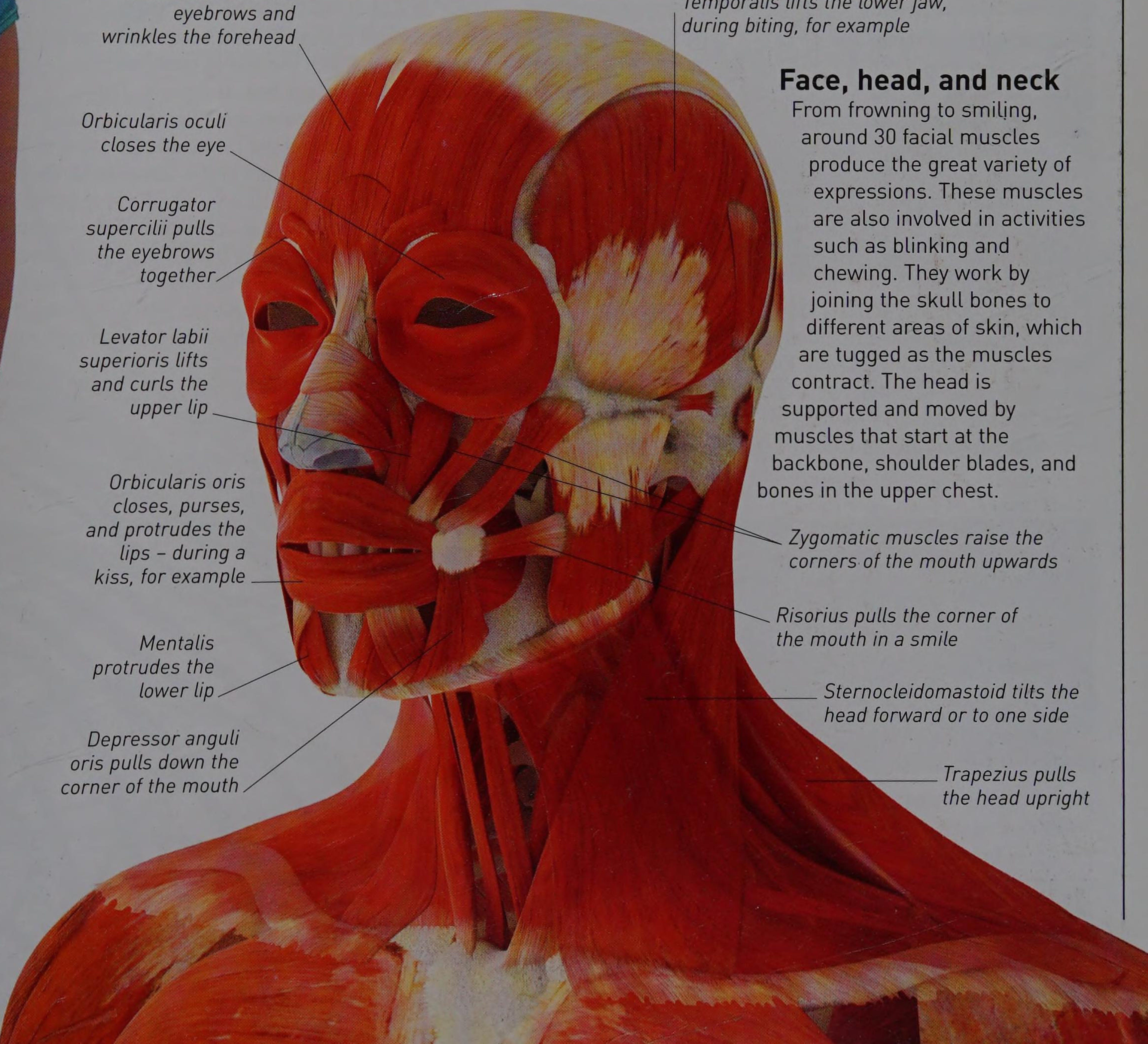


Myofibril contraction

This TEM shows myofibrils, the long cylinders that extend the length of a skeletal muscle fibre, or cell. Here, running from left to right, they are divided into units between the thin, vertical lines. Each unit contains thick and thin filaments, producing the blue-and-pink pattern. The thick and thin filaments slide over each other, making the myofibril – and the entire muscle – shorter.

Face, head, and neck

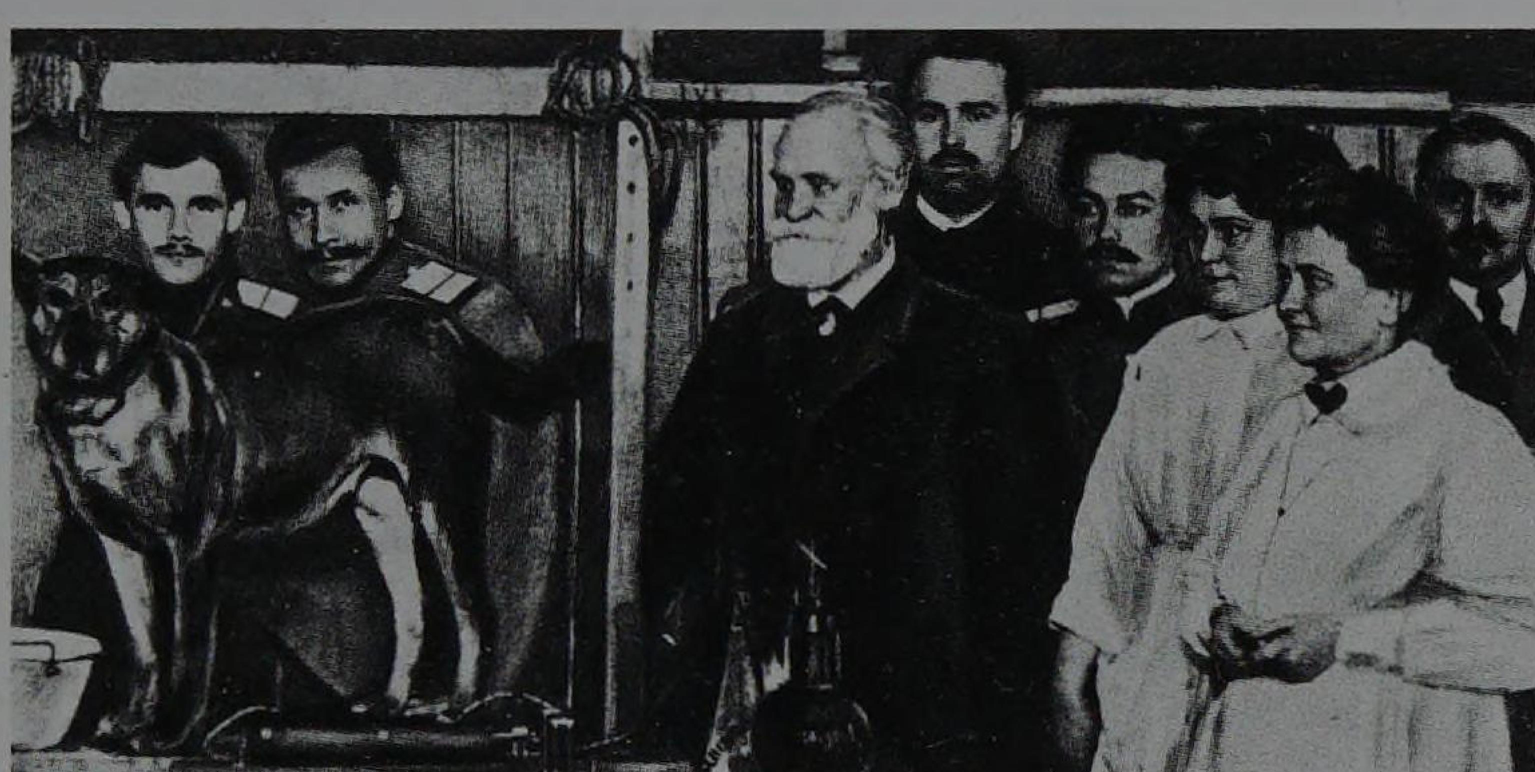
From frowning to smiling, around 30 facial muscles produce the great variety of expressions. These muscles are also involved in activities such as blinking and chewing. They work by joining the skull bones to different areas of skin, which are tugged as the muscles contract. The head is supported and moved by muscles that start at the backbone, shoulder blades, and bones in the upper chest.



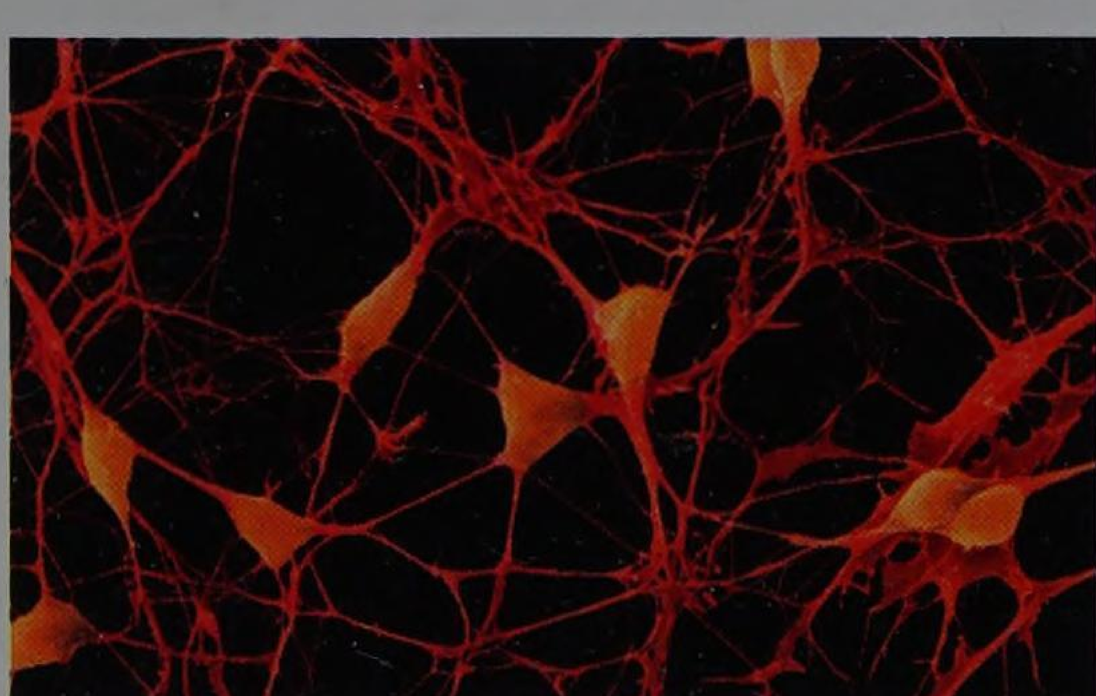
Nerve network
The brain and spinal cord form the control centre of a network of nerves. Nerves are bundles of interconnected neuron cells, and divide to reach all of the body's tissues. Laid end to end, a body's nerves would circle Earth twice.

The nervous system

Without the control and coordination of its nervous system, the body could not function. With split-second timing, our nervous system allows us to feel, see, and hear, to move, and to think and remember – all at the same time. It also automatically controls many internal body processes. It is run by the brain and spinal cord, which form the central nervous system (CNS) and link to the body's network of nerves.



Pavlov's performing dogs
A reflex is an automatic reaction to a particular stimulus, or trigger. Dogs naturally salivate (drool) at the sight and smell of food. Russian scientist Ivan Pavlov (1849–1936) trained some dogs to associate feeding time with the sound of a bell. In time, they drooled when hearing the bell alone.



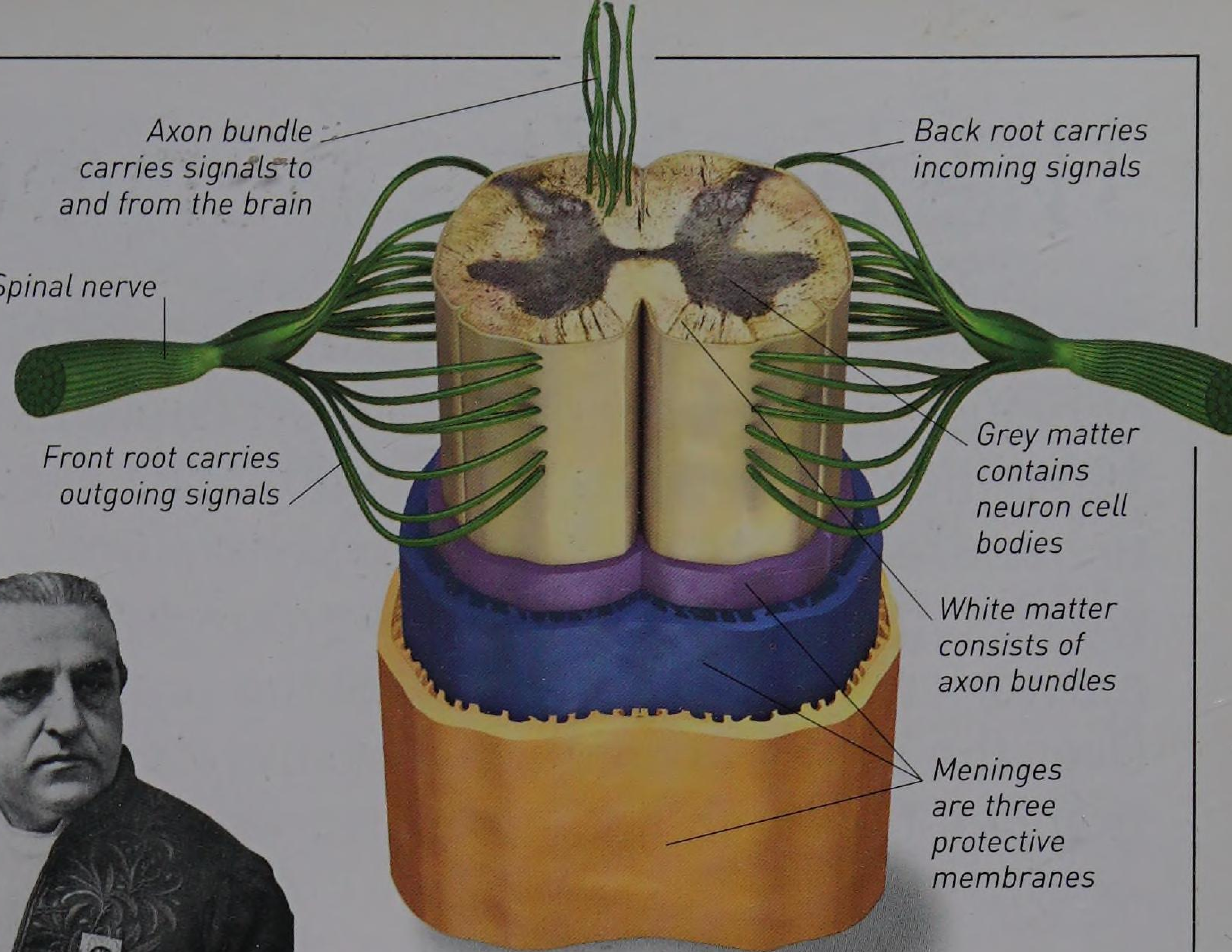
Branches everywhere
These are association neurons in the brain. Each has branching links with thousands of other neurons, forming a communication network with countless routes for nerve signals travelling beween neurons.

Cranial and spinal nerves

The brain – the cerebrum, cerebellum, and brain stem – and the spinal cord function through a constant flow of signals. These arrive and depart through 12 pairs of cranial nerves that start in the brain, and 31 pairs of spinal nerves that start in the spinal cord. Each nerve has sensory neurons, which carry sensations from a body area to the brain, and motor neurons, which carry instructions from the brain to move muscles in that same area. Part of the nervous system automatically controls vital processes that we are unaware of, such as the body's heart rate.

Founder of neurology

French physician Jean-Martin Charcot (1825–93) was a pioneer of neurology, the study of nervous system diseases, and of psychiatry, the branch of medicine that deals with mental illness.

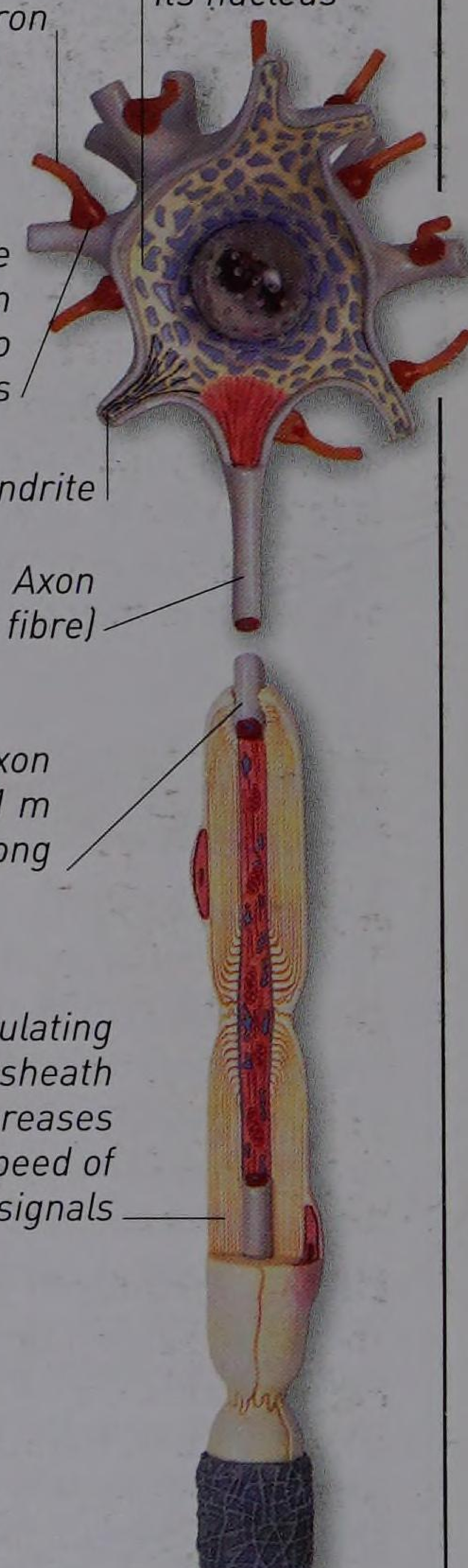


Cross-section of the spinal cord

The spinal cord relays nerve signals between the spinal nerves and the brain. Each spinal nerve has two roots. One contains sensory neurons bringing incoming signals from sense receptors. The other contains motor neurons carrying outgoing signals to the muscles. The spinal cord also controls many automatic body reflexes, such as pulling the hand away from a hot or sharp object.

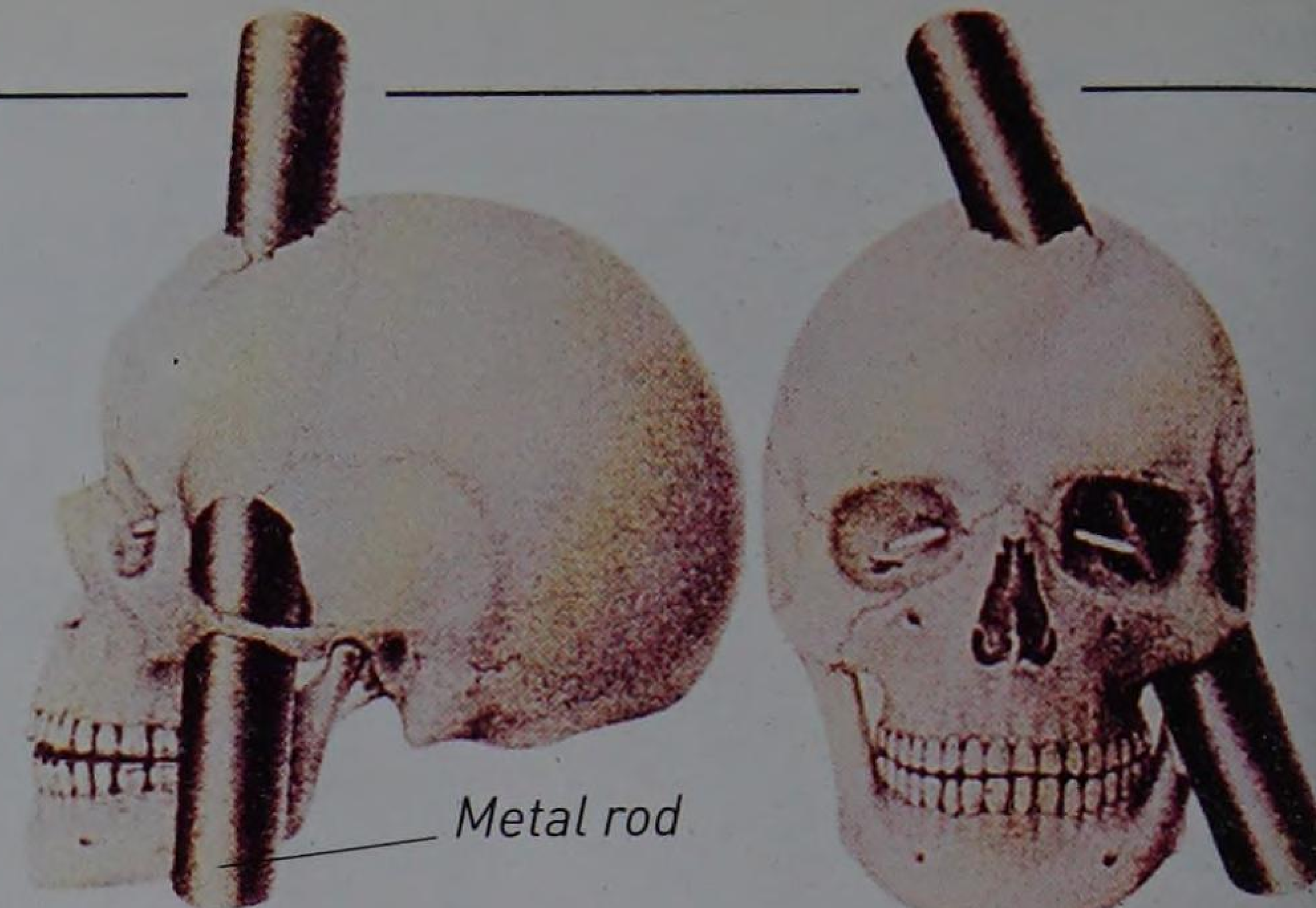
Neuron structure

A neuron is a nerve cell body with many short, branched endings called dendrites and one long axon, or nerve fibre. Dendrites receive nerve signals from other neurons across junctions called synapses. Axons carry nerve signals away from the cell body, across synapses with other neurons or with muscles.



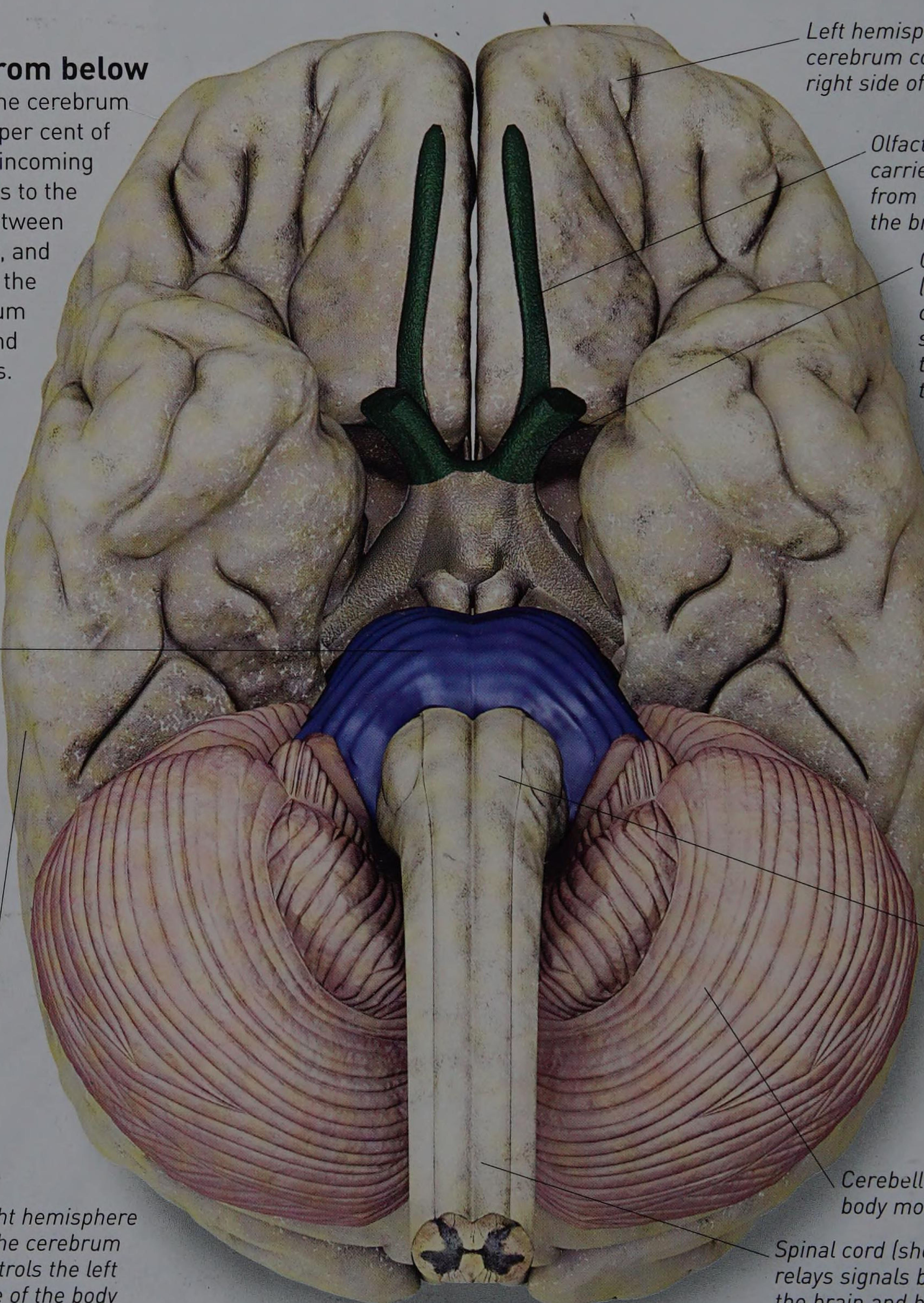
The brain

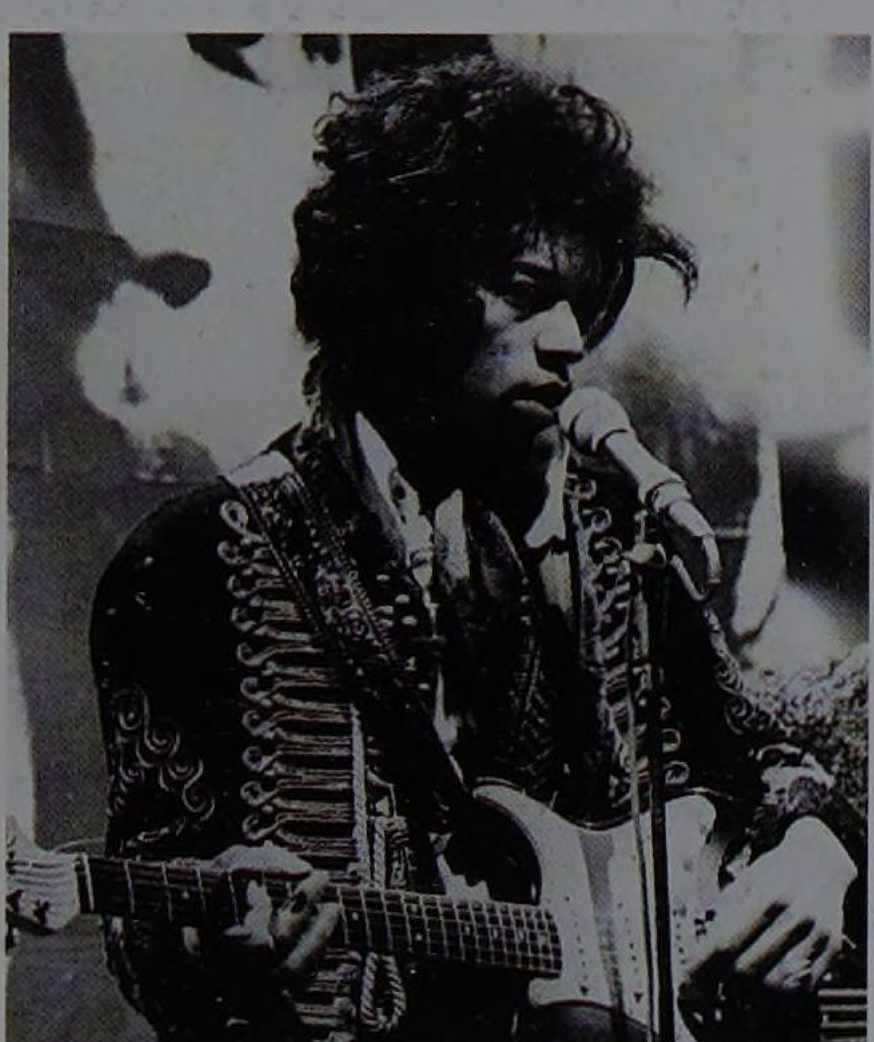
The brain is our most complex organ and our nervous system's control centre. It contains 100 billion neurons (nerve cells), each linked to hundreds or thousands of other neurons, which together form a vast communication network with incredible processing power. Over the past two centuries, scientists have mapped the brain and how it works.



Hole in the head
Phineas Gage worked in a quarry in the USA. In 1848, a gunpowder accident blew a metal rod through the left frontal lobe of his brain. Gage survived, but he changed from contented and polite to moody, and foul-mouthed – living proof that the front of the brain is involved in personality.

The brain from below
The brain has three main parts. The cerebrum dominates the brain and makes up 85 per cent of its weight. It processes and stores incoming information and sends out instructions to the body. The brain stem relays signals between the cerebrum and the spinal cord, and controls automatic functions, such as the heart rate and breathing. The cerebellum is responsible for controlling balance and posture and for coordinating movements.

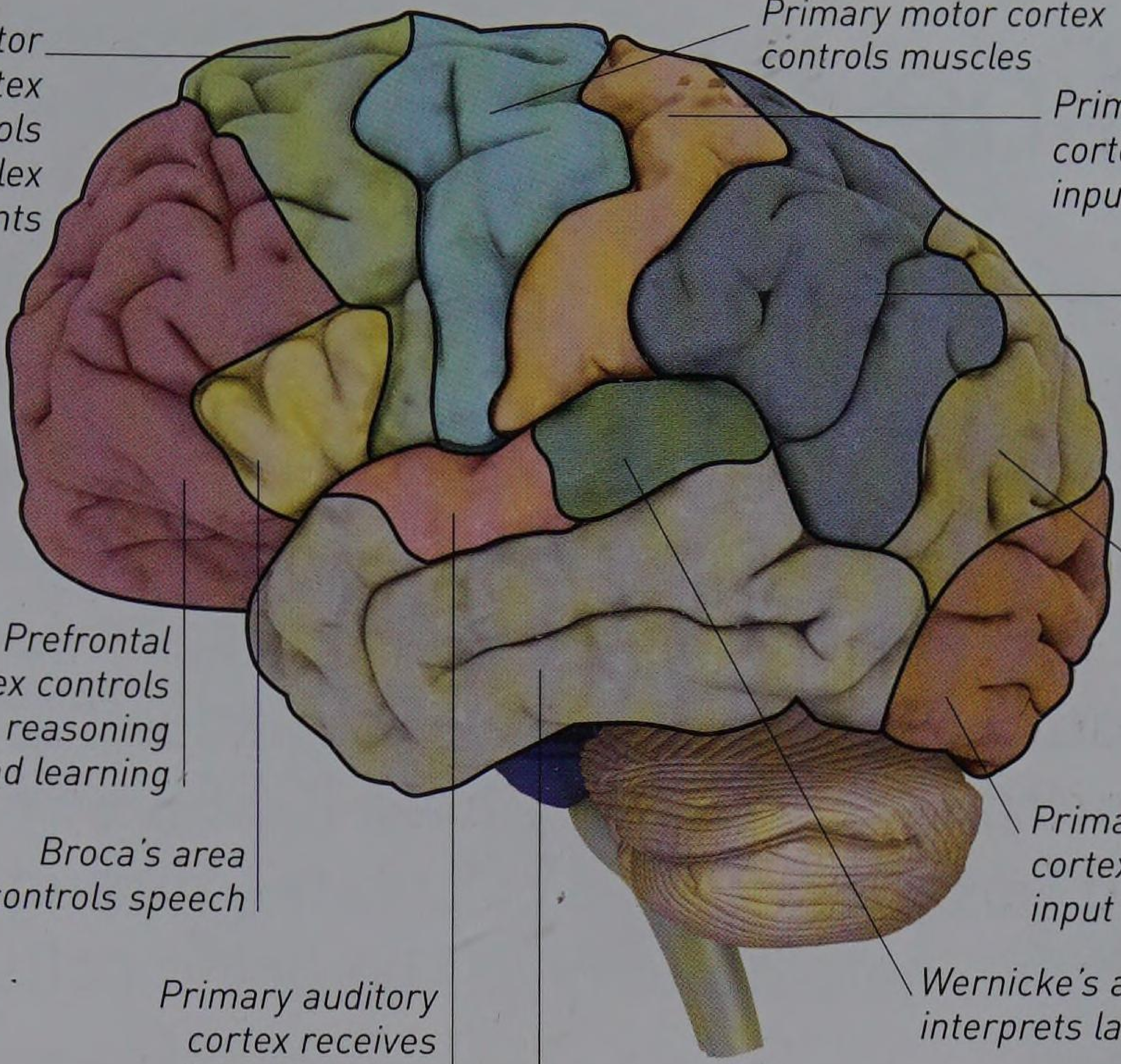




Left and right
The right hemisphere (half) of the cerebrum receives sensory input from, and controls the movements of, the left side of the body, and vice versa. The right side of the brain also handles face recognition, and creative abilities such as music, while the left side controls language, problem solving, and mathematical skills. Left-handed people, such as rock guitarist Jimi Hendrix (1942–70), often excel in the creative arts and music.

Site of speech

French physician Paul Pierre Broca (1824–80) had a patient with a limited ability to speak. After the patient died, Broca found a damaged patch on his left cerebrum. He realized this area coordinated the muscles of the larynx and mouth that are used for speaking.

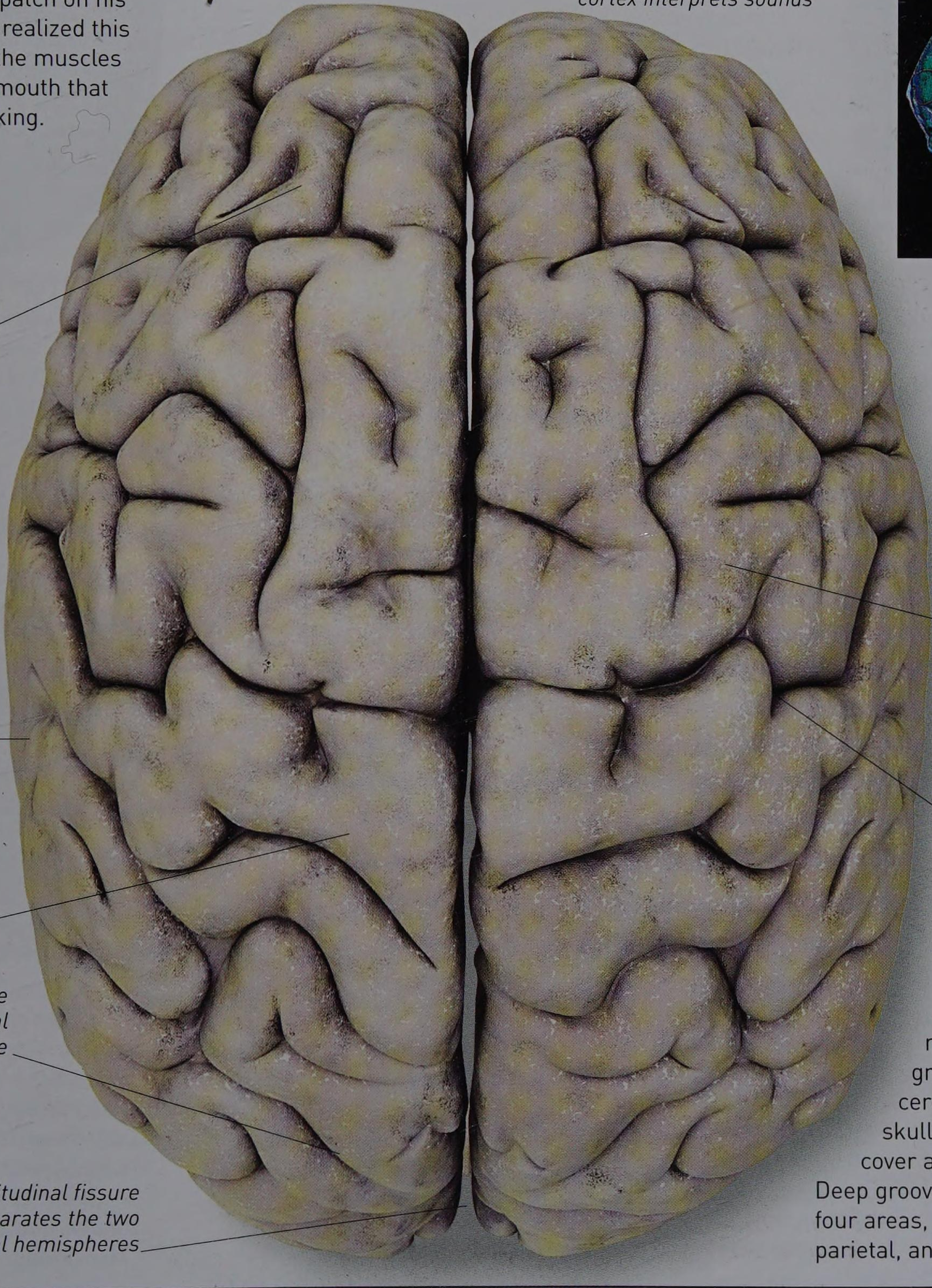


Brain map

Different areas of the cerebral cortex carry out specific tasks, as shown in this map of the left hemisphere. Sensory areas of the cortex deal with input from the sensory detectors. Motor areas of the cortex control the body's movement. Most of the cortex is made up of association areas, which interpret and analyse information used in learning and memory.

Blood supply

This angiogram shows the brain's blood supply. The brain makes up only two per cent of the body's weight, but receives 20 per cent of the body's total blood supply. This delivers the oxygen and glucose (sugar) that the brain requires to function normally.



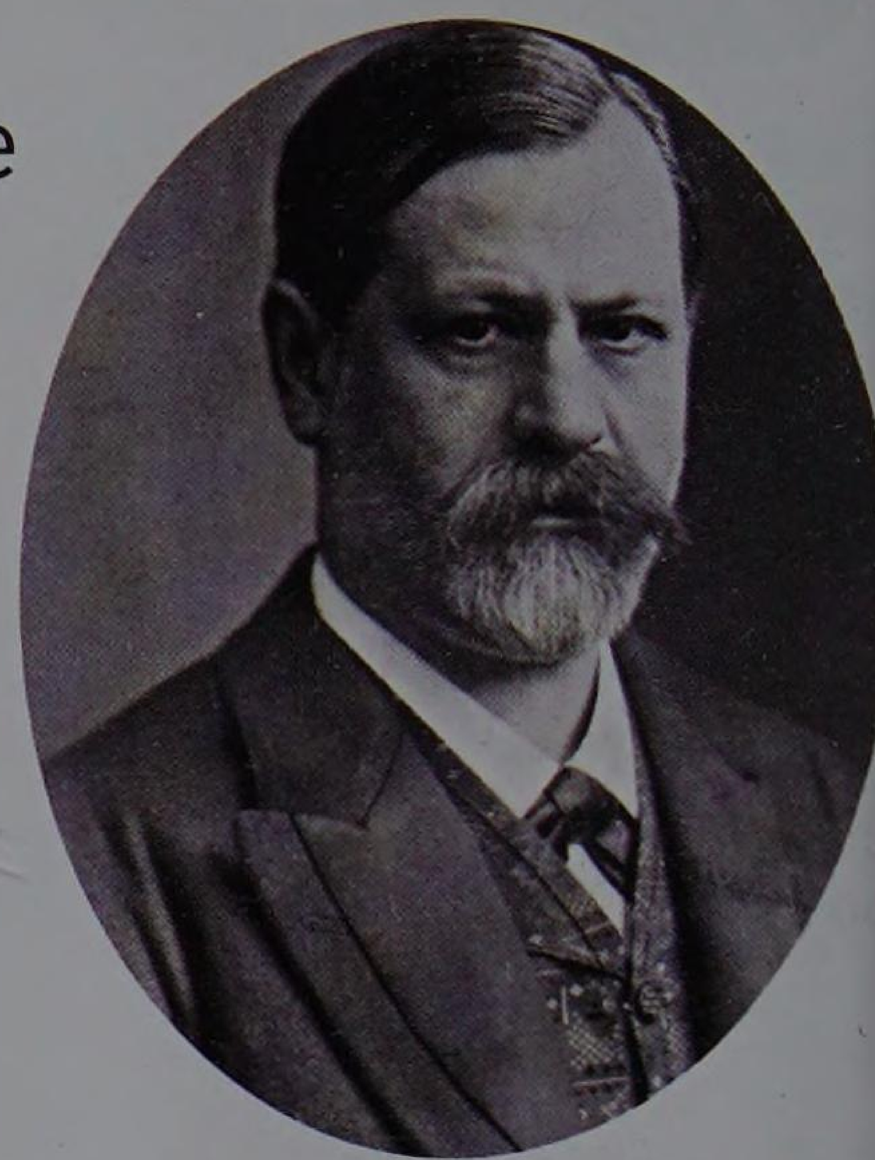
The brain from above

The surface layer of the cerebrum, called the cerebral cortex, is heavily folded with ridges and grooves. These greatly increase the surface area of cerebral cortex that can fit inside the skull. If laid out flat, the cortex would cover about the same area as a pillow. Deep grooves divide each hemisphere into four areas, called the frontal, temporal, parietal, and occipital lobes.

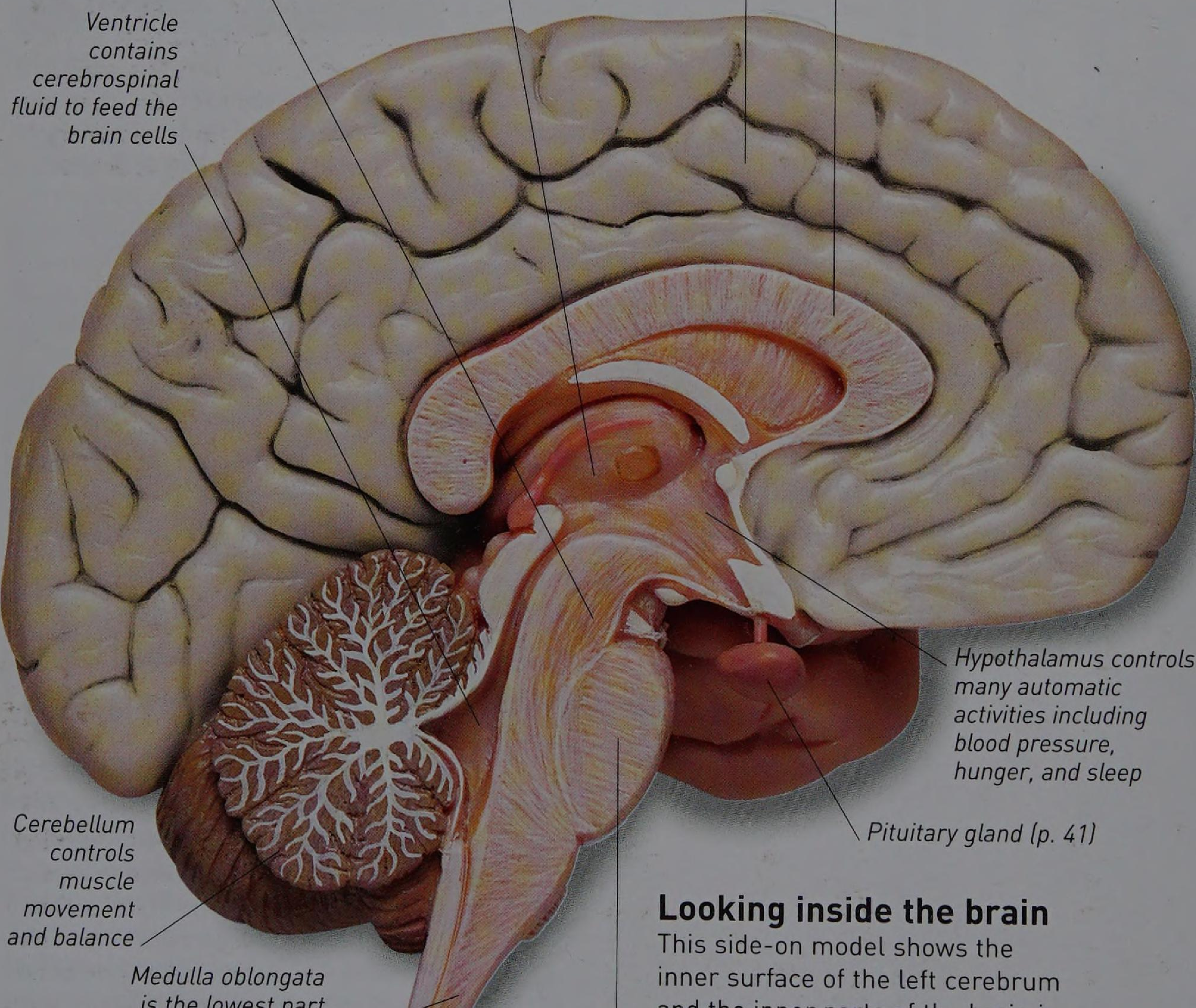
Inside the brain

Liquid brainpower
Long ago, a mystical animal spirit was said to fill the brain's ventricles. This 17th-century image links each ventricle to a different mental quality, such as imagination.

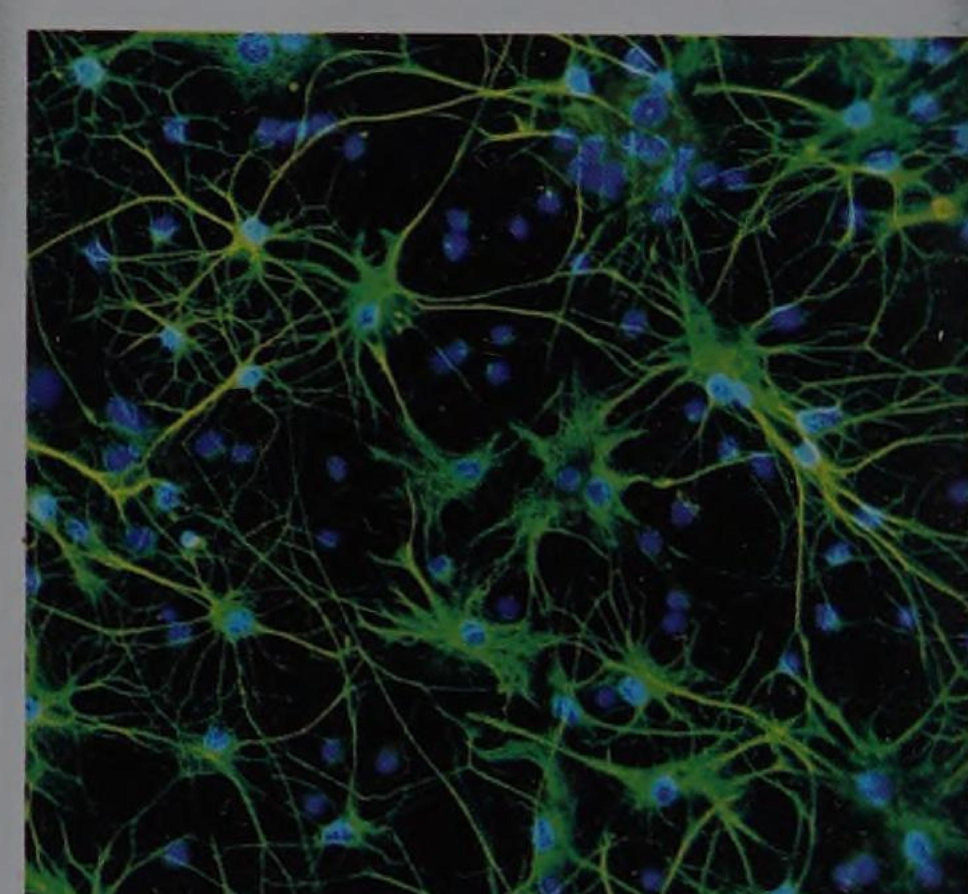
Deep inside the brain, under the cerebrum, the thalamus acts as a relay station for incoming nerve signals, and the hypothalamus automatically controls a vast array of body activities. The limbic system is the emotional centre of the brain, dealing with instincts, fears, and feelings. Inside the cerebrum, linked chambers called ventricles are filled with cerebrospinal fluid (CSF). CSF is produced by blood and circulates through the ventricles, helping to feed the brain cells.



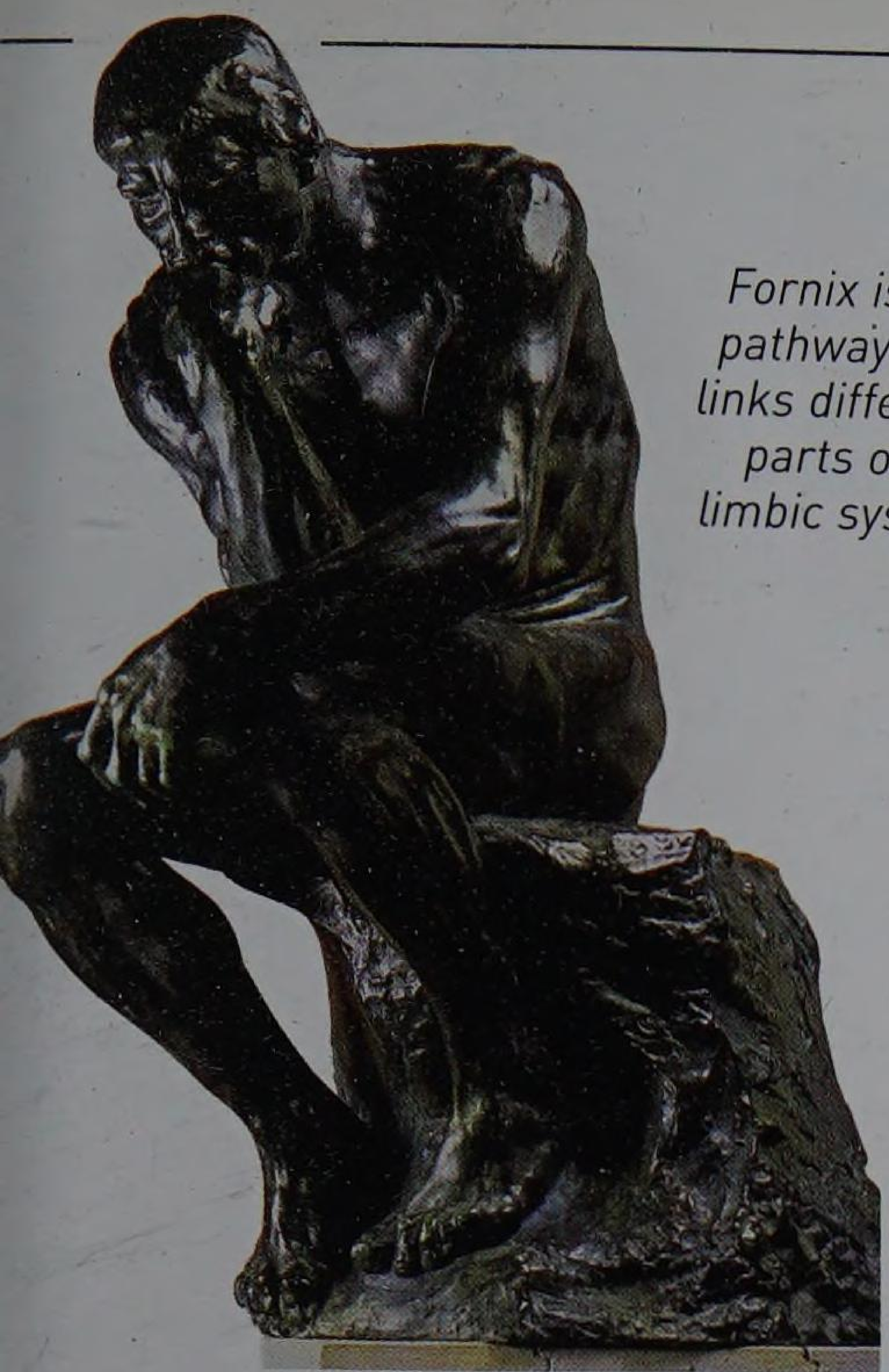
Matters of the mind
Austrian physician Sigmund Freud (1856–1939) used psychoanalysis to treat mental illness by investigating the unconscious mind. Since Freud, pyschiatrists have linked mental disorders to abnormalities in the brain's structure and its biochemical workings.



Looking inside the brain
This side-on model shows the inner surface of the left cerebrum and the inner parts of the brain in cross-section. The thalamus sits in the centre of the brain. The cerebellum is at the back of the brain, behind the brain stem.

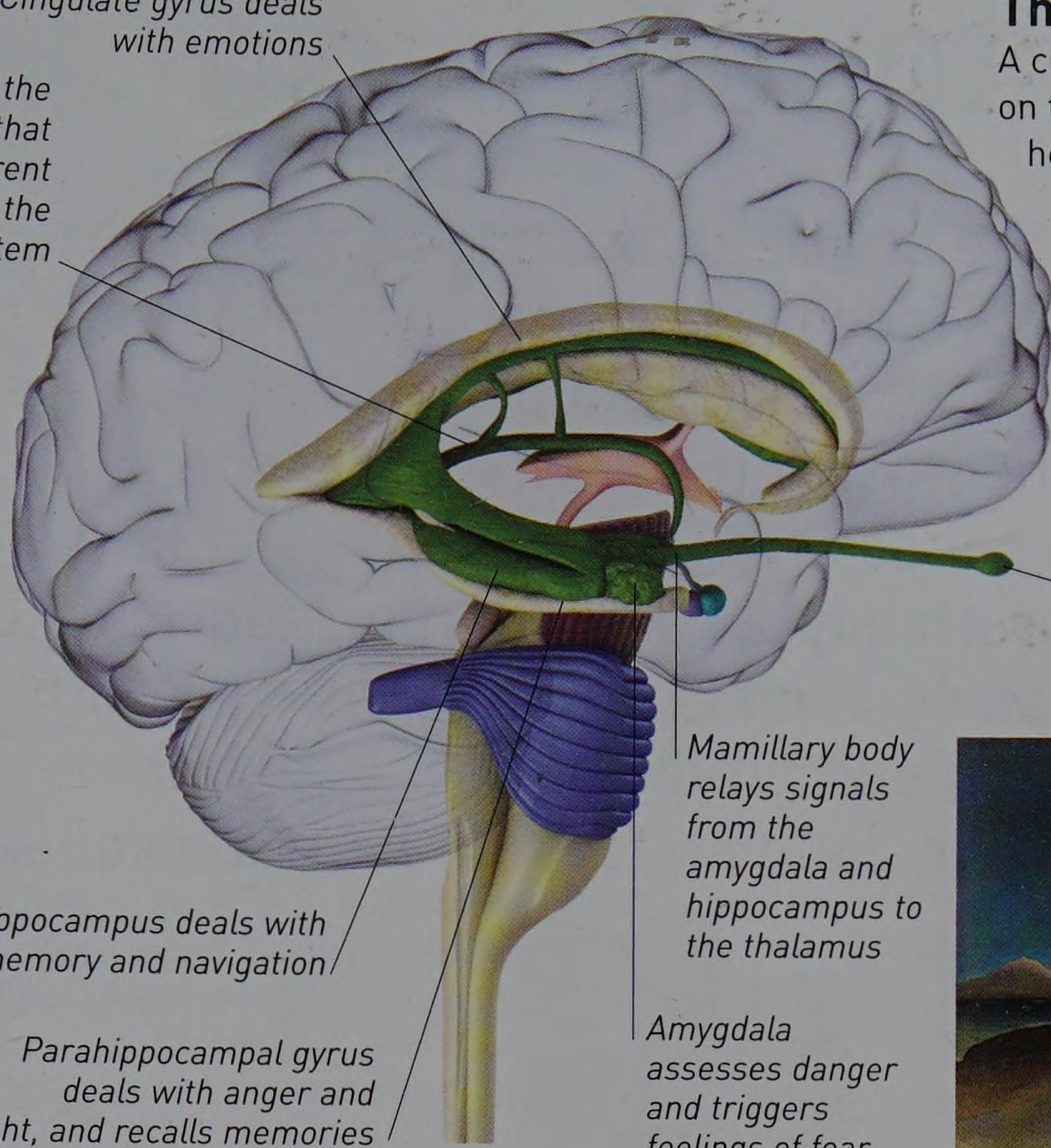


Support cells
Over 90 per cent of cells in the nervous system are not neurons (nerve cells) but glial, or support, cells. Astrocytes, a type of glial cell found in the cerebral cortex, help to supply neurons with nutrients. Other functions of glial cells include destroying bacteria and insulating axons (nerve fibres).



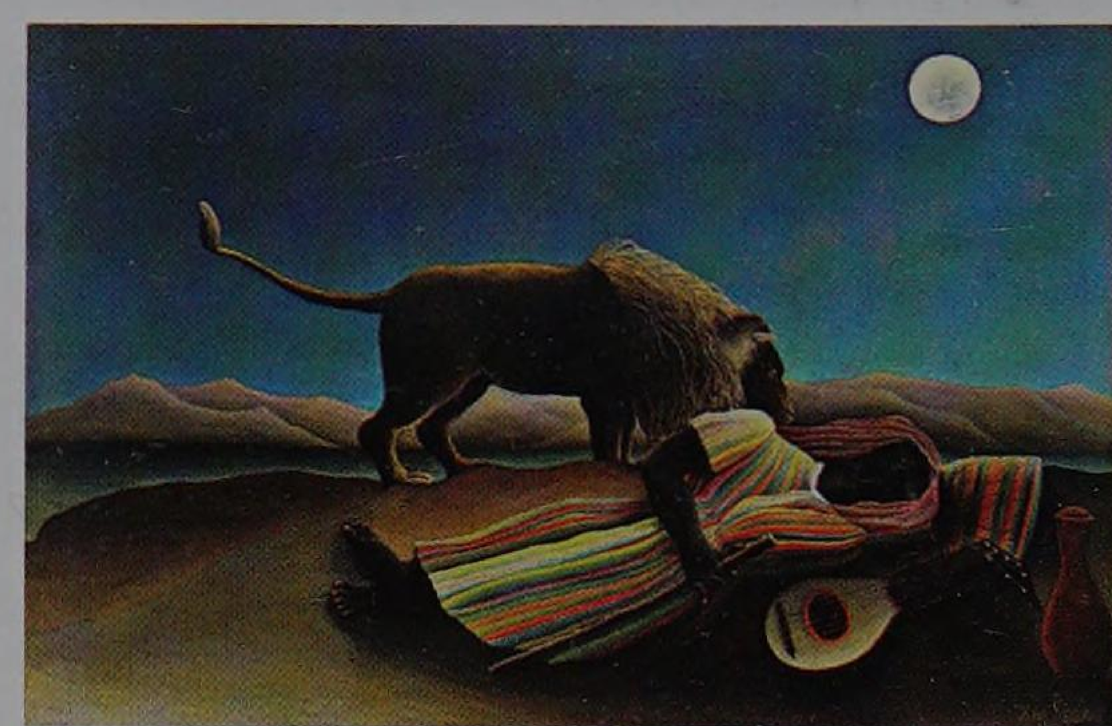
Deep thought

French sculptor Auguste Rodin (1840–1917) portrayed deep concentration in his statue *The Thinker*. When we want to think hard about a matter, we stare into space, almost unseeing, so that we can concentrate.



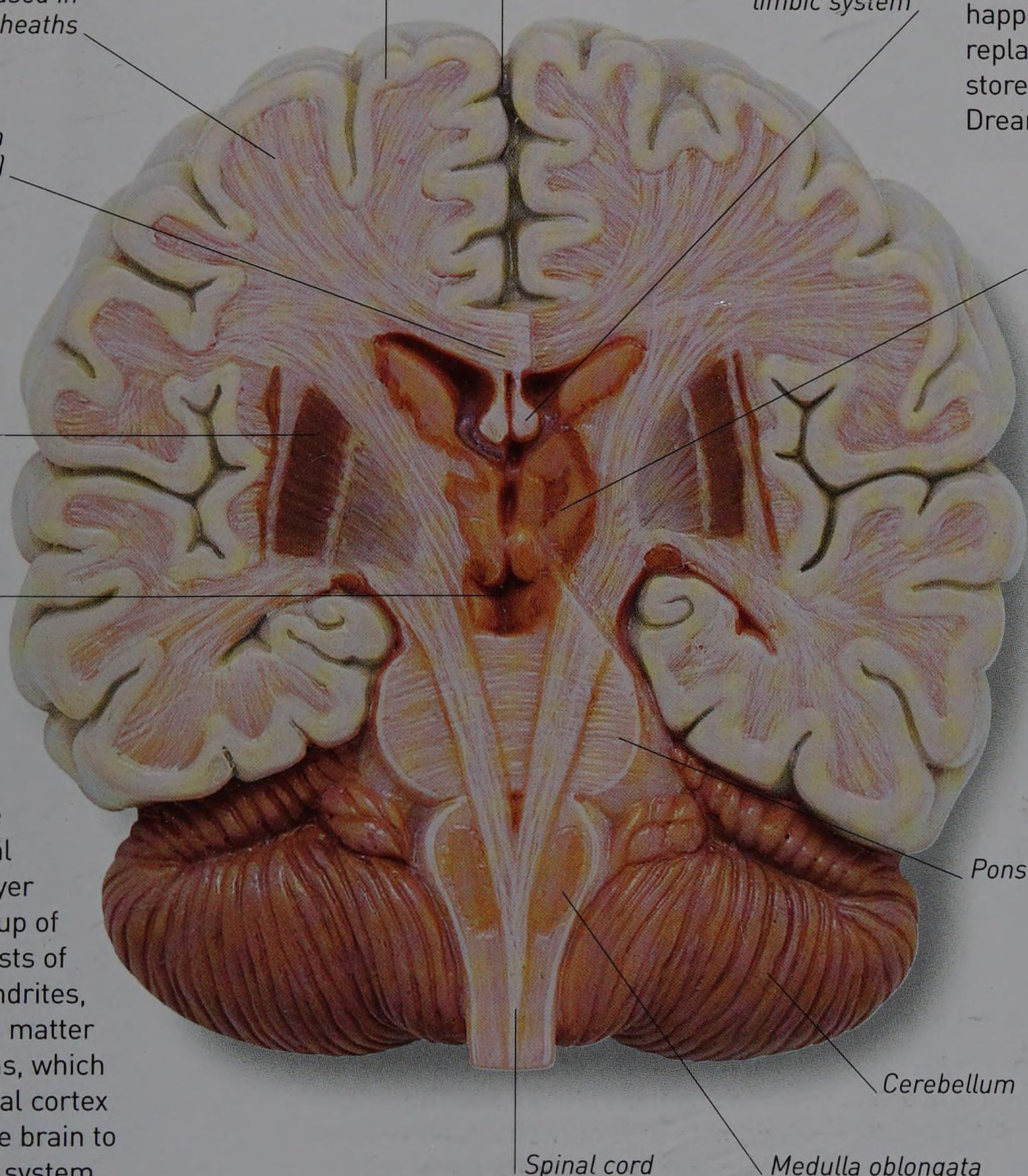
The limbic system

A curve of linked structures is located on the inner surface of each cerebral hemisphere and around the top of the brain stem. It deals with emotions such as pleasure, anger, fear, hope, and sadness, and helps us to store memories. As the sense of smell is linked to the limbic system, certain odours can trigger feelings and memories.



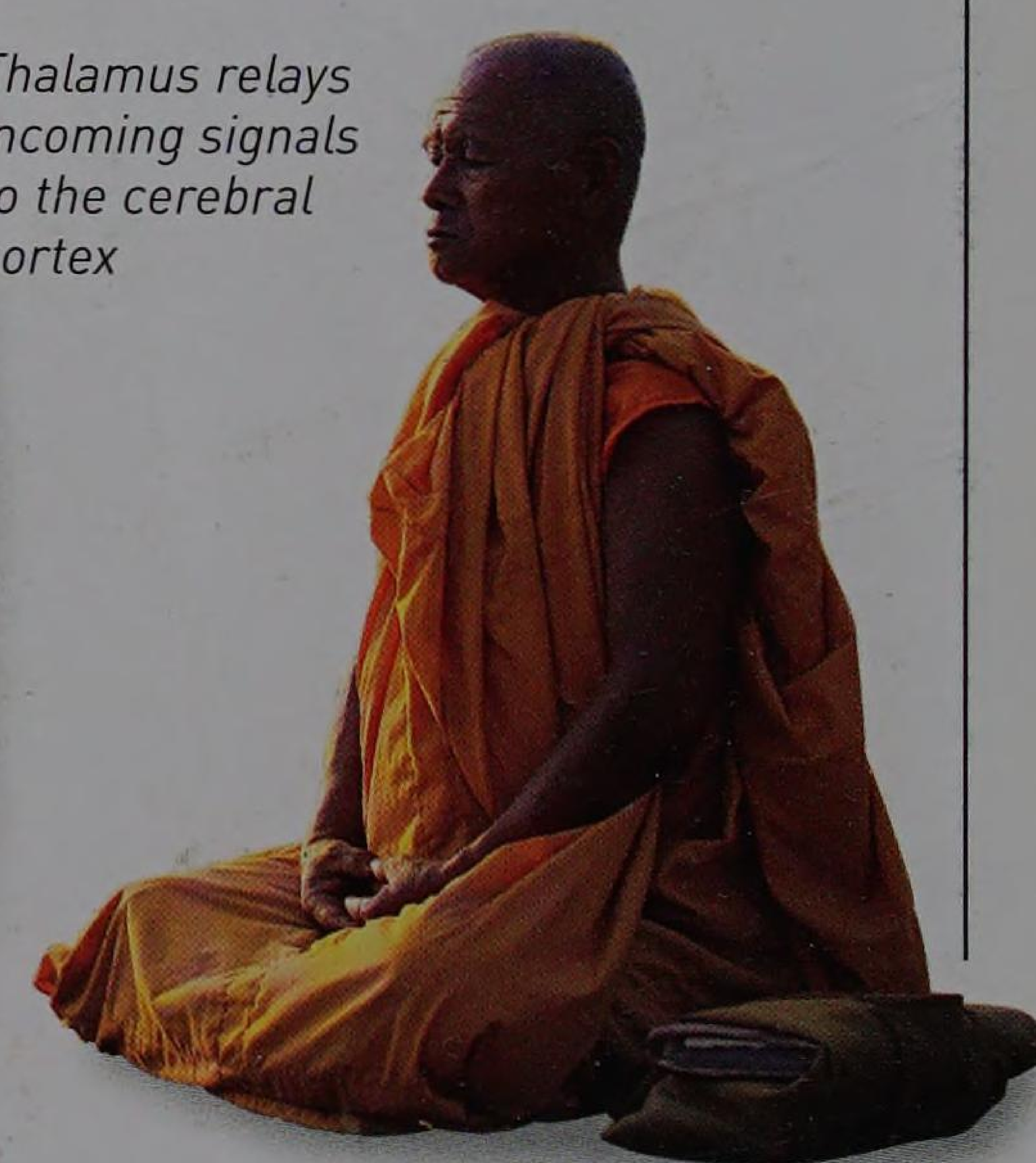
Sweet dreams

French artist Henri Rousseau (1844–1910) painted a musician dreaming about a lion in *The Sleeping Gypsy*. In our dreams, real experiences can be mixed up with strange happenings. While we sleep, the brain replays recent experiences at random and stores significant events in the memory. Dreaming is a side effect of this activity.



Grey and white matter

This vertical cross-section gives a front view of the parts of the cerebrum. The cerebral cortex – the surface layer of the brain – is made up of grey matter. This consists of neuron cell bodies, dendrites, and short axons. White matter consists of longer axons, which join parts of the cerebral cortex together, or connect the brain to the rest of the nervous system.



Mind over matter

Scientists continue to explore how the brain works. Some people look beyond its nerve signals and chemical processes, and believe that techniques such as meditation, performed here by a Buddhist monk, can carry the mind beyond the physical boundaries of the body.

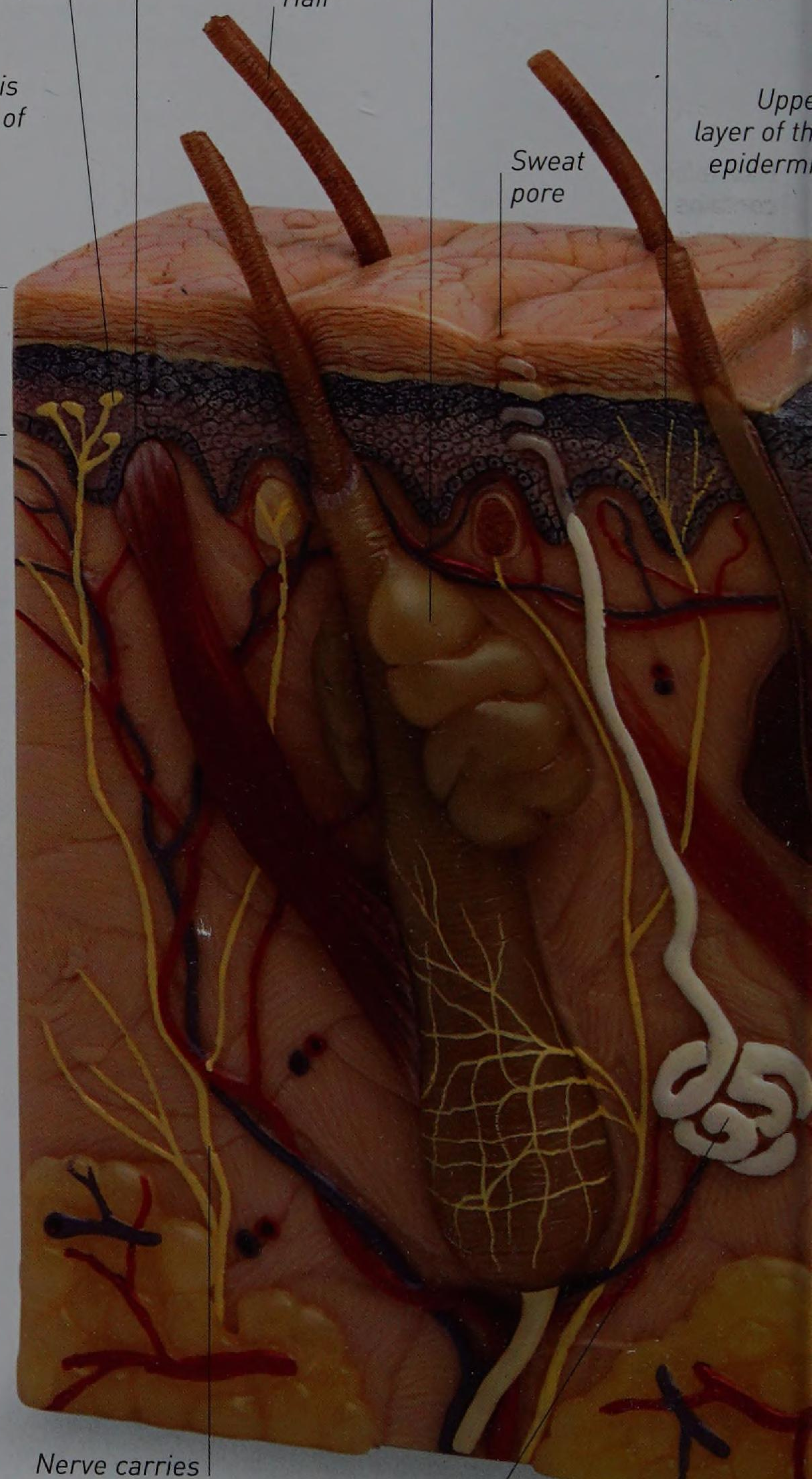
Skin and touch

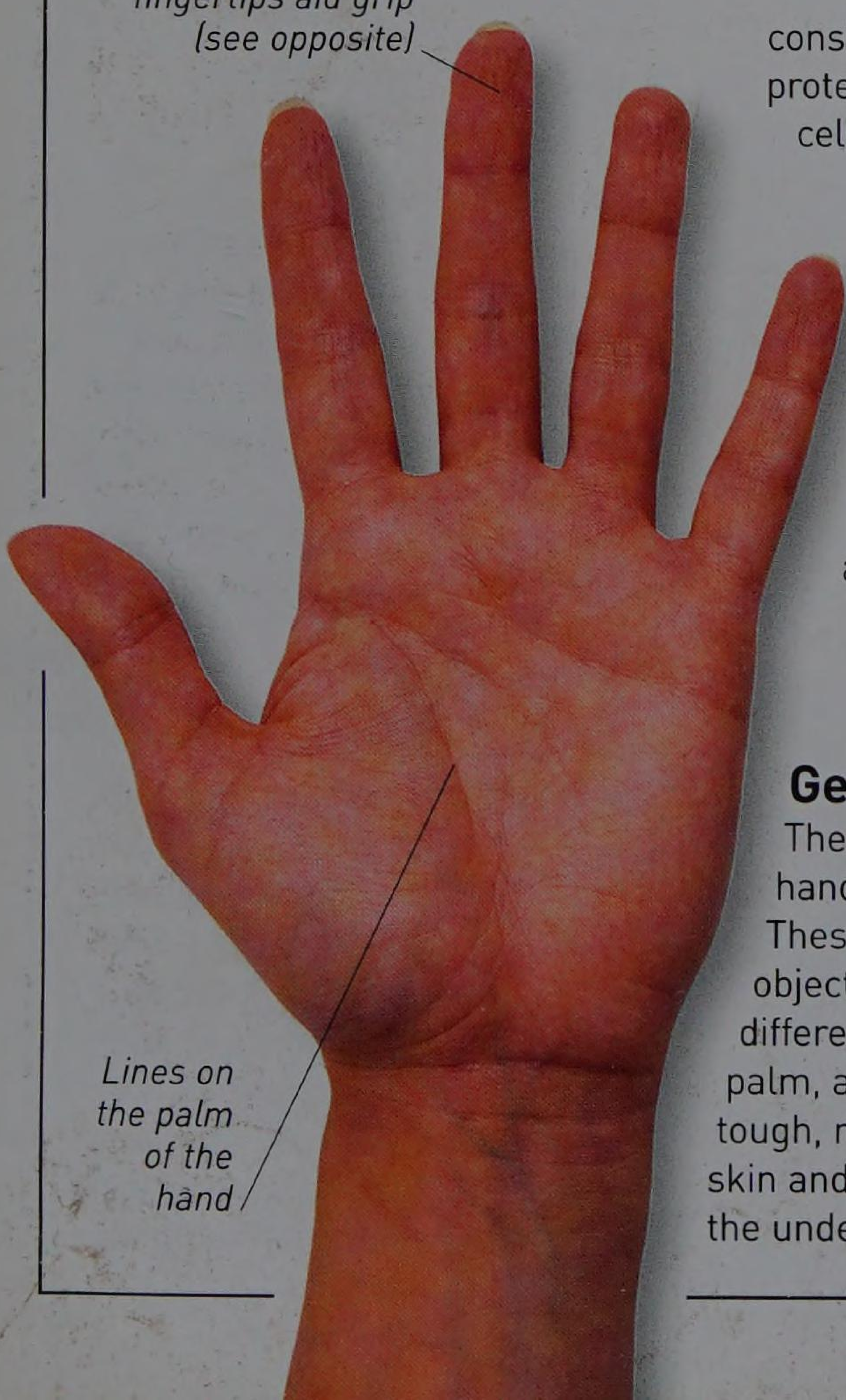
As well as its role in the sense of touch, skin has many other jobs. Its tough surface layer, the epidermis, keeps out water, dust, germs, and harmful ultraviolet rays from the Sun. Underneath is a thicker layer, the dermis, which is packed with sensory receptors, nerves, and blood vessels. It helps steady our body temperature at 37°C (98.6°F) by releasing sweat. Hair and nails provide additional body covering and protection.

Cooling the body
This is one of about three million sweat pores in the skin's surface. When sweat glands in the dermis release sweat through the pores, the process draws heat from the body and cools it down.

Fingertip reading
The Braille system enables people with sight problems to read using the sense of touch. It uses patterns of raised dots to represent letters and numbers, which are felt through the sensitive fingertips. The system was devised in 1824 by French teenager Louis Braille (1809–52), who was blinded at three years old.

Under your skin
The upper surface of the epidermis consists of dead cells filled with a tough protein, keratin. The skin flakes as dead cells wear away and are replaced with new ones produced in the lowest layer of the epidermis. The thicker dermis layer contains the sense receptors that help the body detect changes in temperature, touch, vibration, pressure, and pain. The dermis also houses coiled sweat glands and hair follicles. Oily sebum keeps the skin and hair soft and flexible.

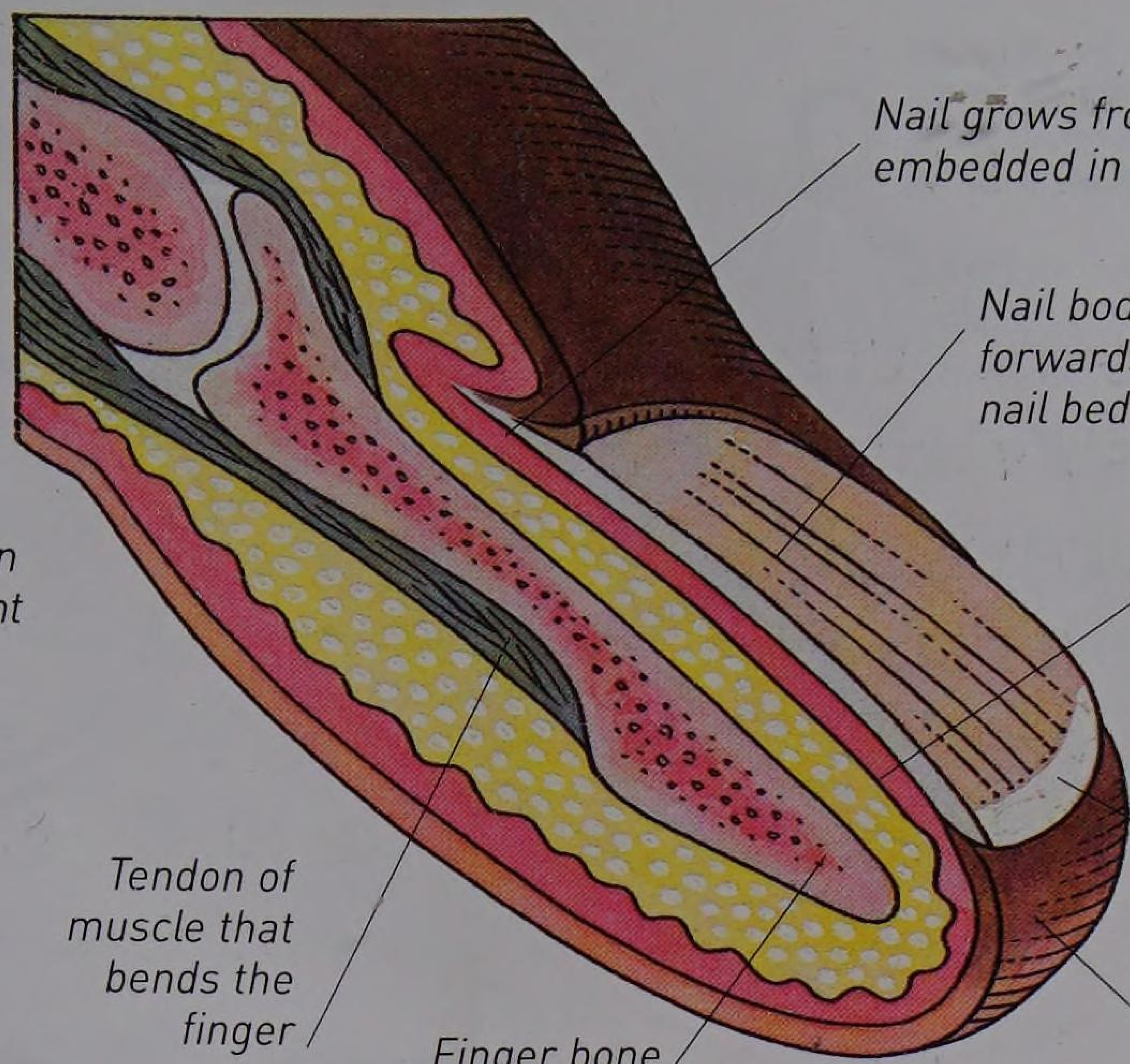




Get a grip
The skin on the palm of the hand is covered with ridges. These help the hand to grip objects when performing different tasks. Beneath the palm, a triangle-shaped sheet of tough, meshed fibres anchors the skin and stops it from sliding over the underlying fat and muscle.

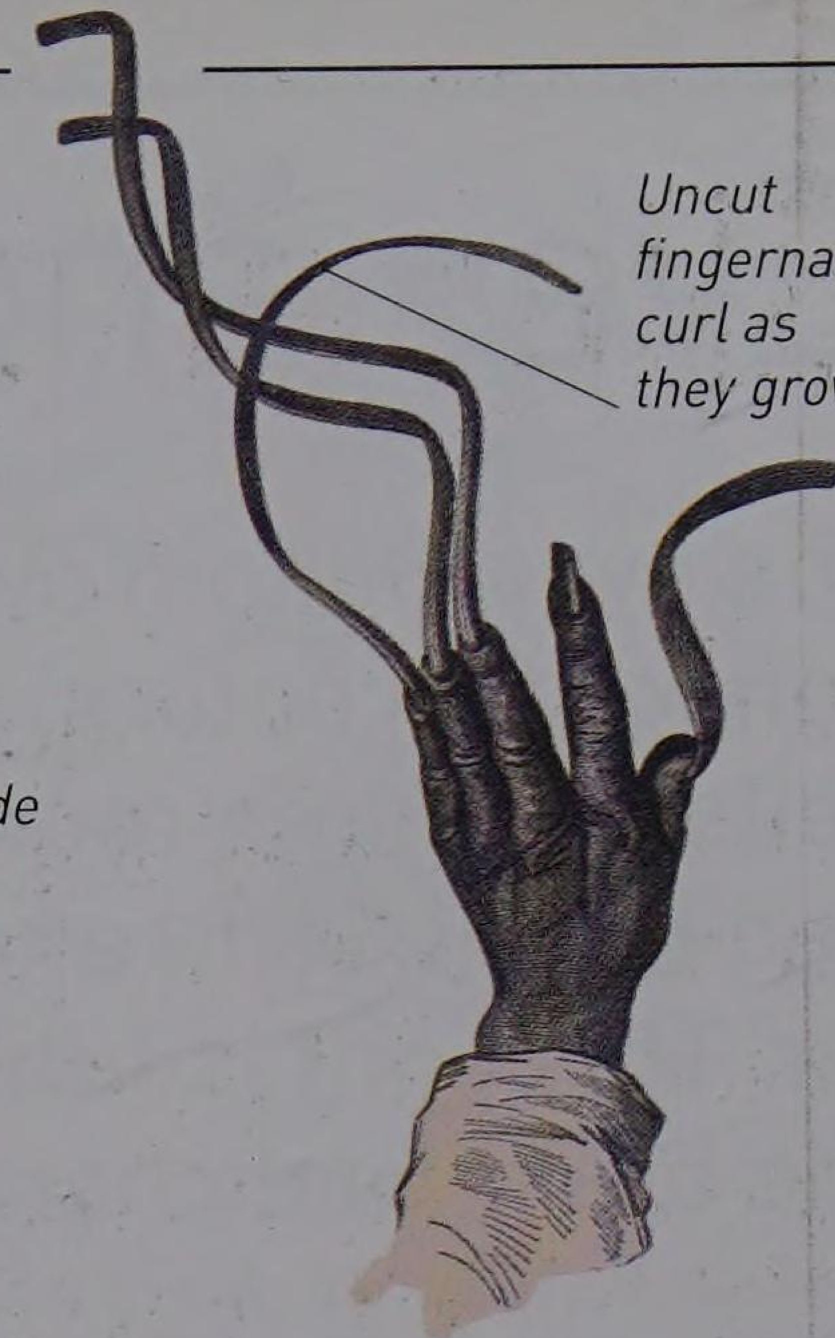
Fingerprints

he skin on the fingers, toes, alms, and soles is folded into swirling patterns of tiny ridges. he ridges help this skin to rip, aided by sweat released hrough pores along each idge. When fingers touch smooth surfaces, such as lass, their ridges leave behind sweaty patterns, or prints, eaturing arches, loops, and whorls. Each human has a nique set of fingerprints.



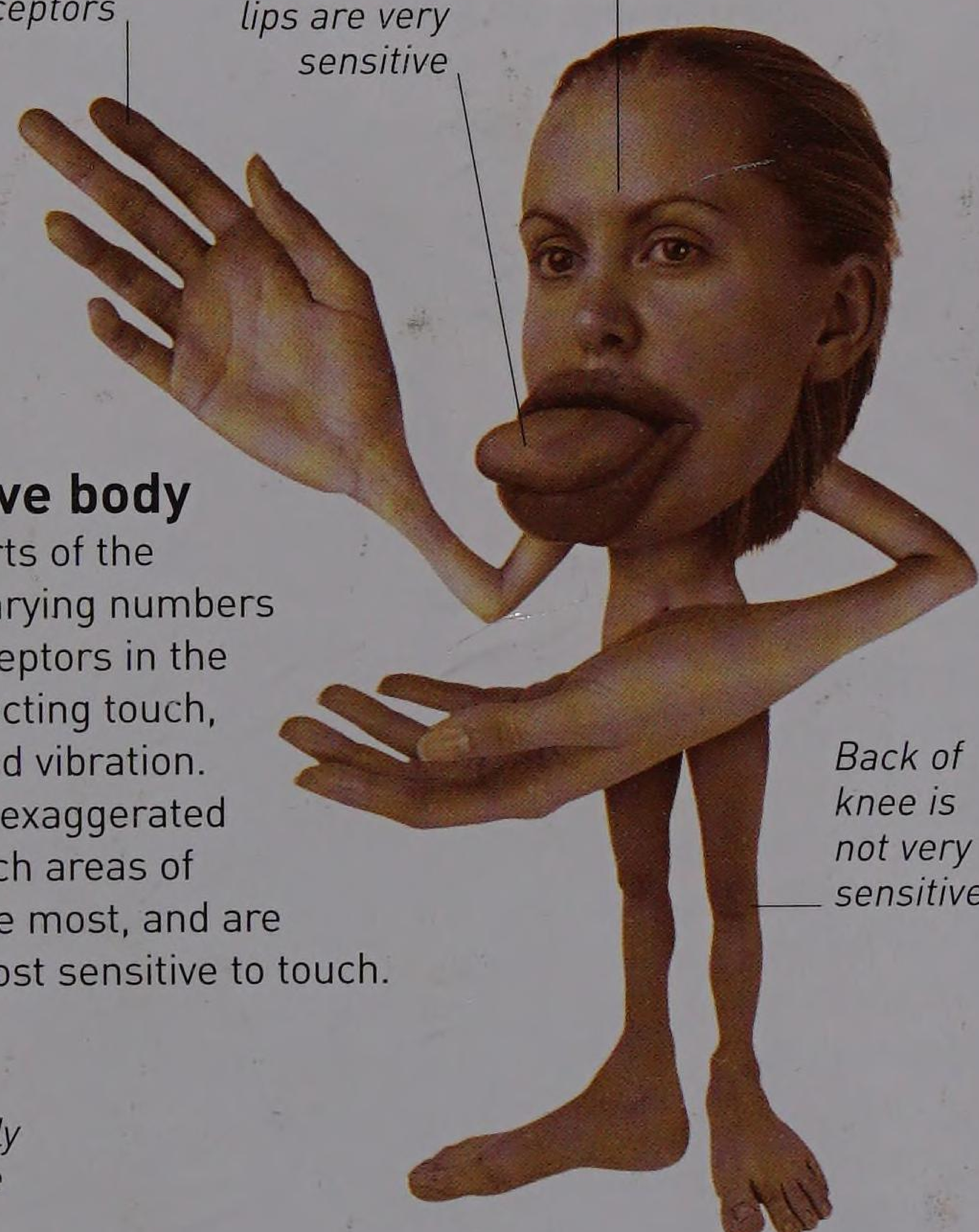
Insensitive nails

Nails protect the ends of fingers and toes. They are hard extensions of the epidermis, made from dead cells filled with keratin. Each nail grows from new cells produced in the root. These push the nail body forwards over the nail bed as it grows.



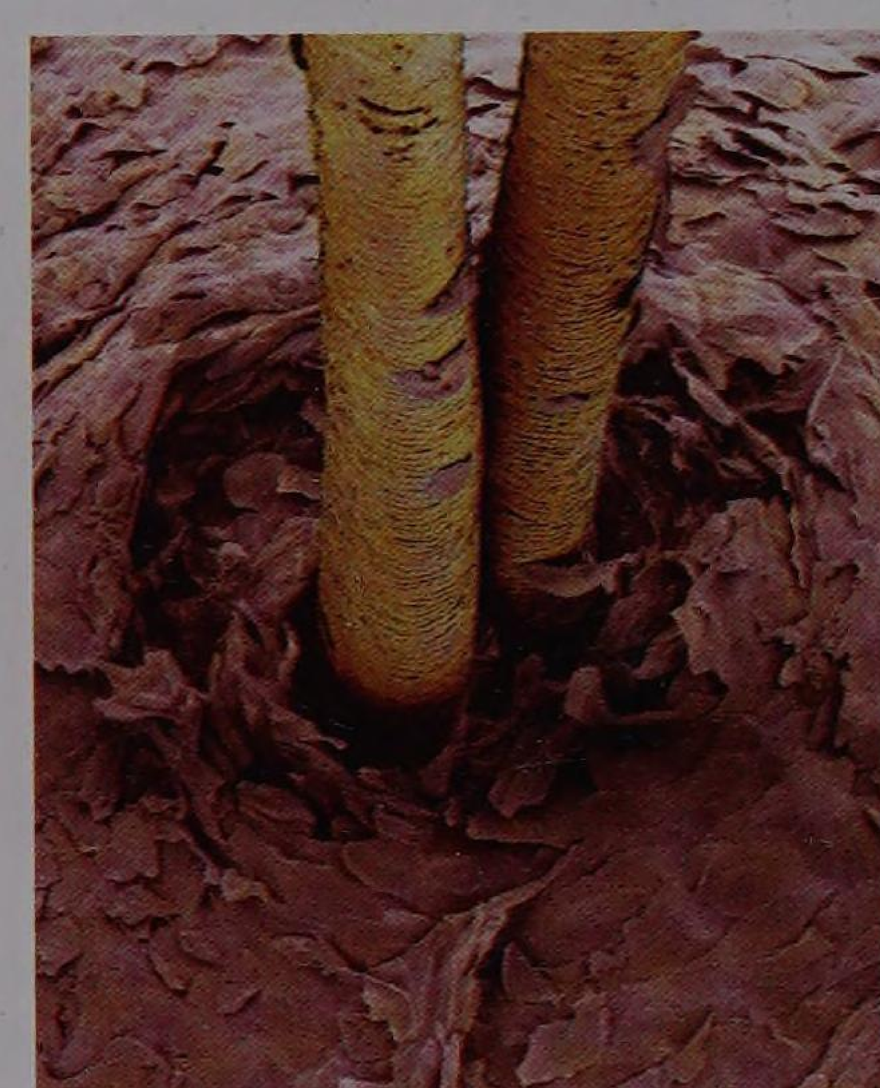
Nail growth

A typical fingernail grows about 3 mm (0.12 in) in a month. The nails on the longer fingers grow faster than those on the shorter ones. Fingernails also grow faster in the summer months than in winter. Toenails grow three or four times more slowly.



A sensitive body

Different parts of the body have varying numbers of sense receptors in the skin for detecting touch, pressure, and vibration. This body is exaggerated to show which areas of skin have the most, and are therefore most sensitive to touch.



Dead hairs

These hair shafts in the skin grow from living cells at the base of the follicle. As the cells push upwards, they fill with keratin and die. Short, fine hairs cover much of the body. Longer, thicker hairs protect the scalp from harmful sunlight and prevent heat loss.

Skin colour

Skin colour depends on how much melanin, or brown pigment (colouring), it contains. Melanin is produced by cells in the lowest layer of the epidermis. It protects against the harmful, ultraviolet rays in sunlight, which can damage skin cells and the tissues underneath. Sudden exposure of pale skin to strong sunlight can produce sunburn.

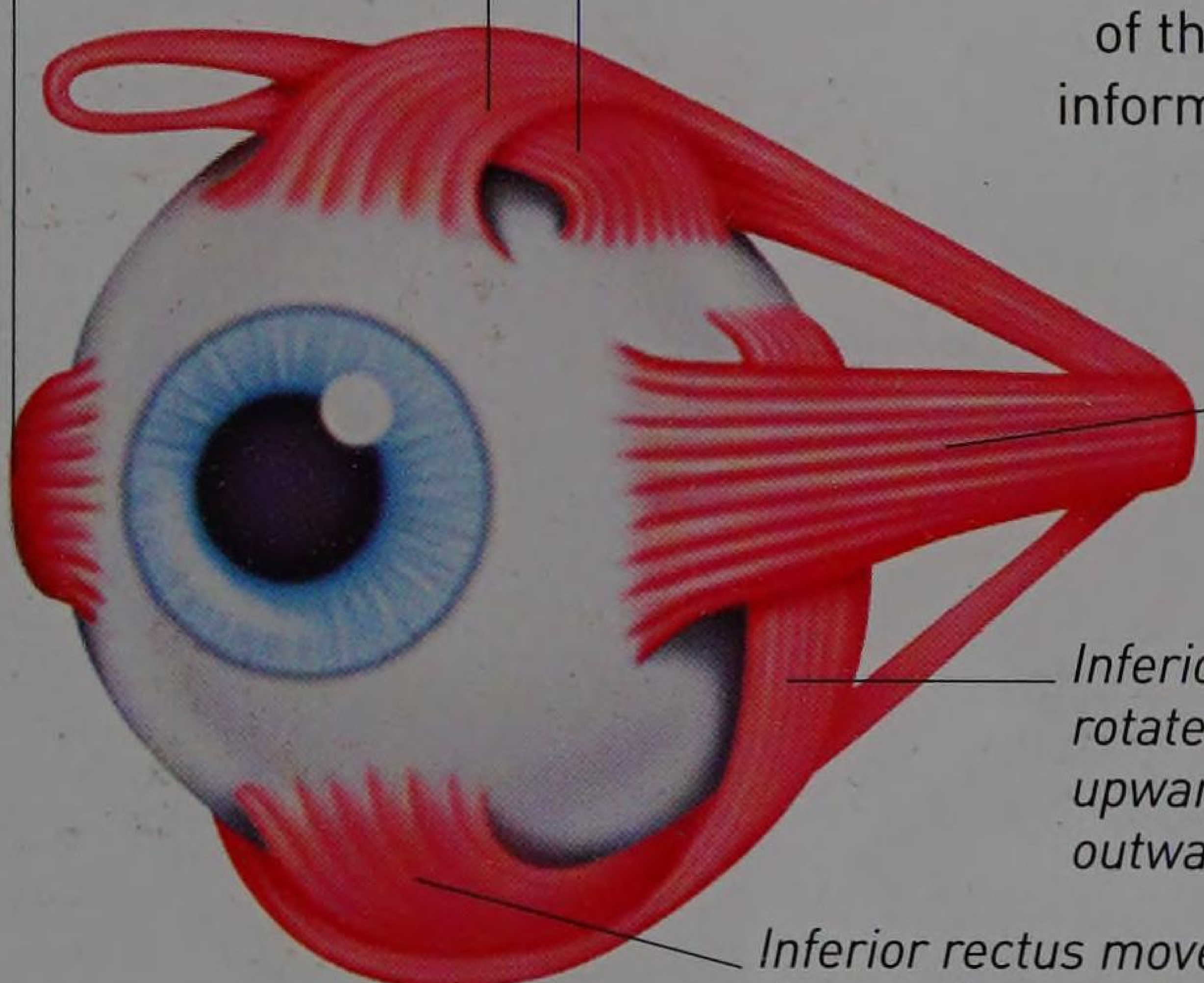
Eyes and seeing

The eyes contain over 70 per cent of the body's sensory receptors, in the form of light-detecting cells. Our eyes move automatically, adjust to dim and bright light, and focus light from objects near or far. This light is turned into electrical signals, sent to the brain, and changed into the images we see.

Cross-eyec
This Arabic drawing, nearly 1,000 years old shows how the optic nerves cross. Half of the nerve fibres from the right eye pass to the left side of the brain, and vice versa.

Outer layers

The wall of the eyeball has three layers. Outermost is the tough sclera, visible at the front as the white of the eye, except where the clear cornea allows light in. Next is the choroid, filled with blood vessels that supply the other two layers. The innermost layer is the retina. Millions of light-detecting cells at the back of the retina send image information to the brain.

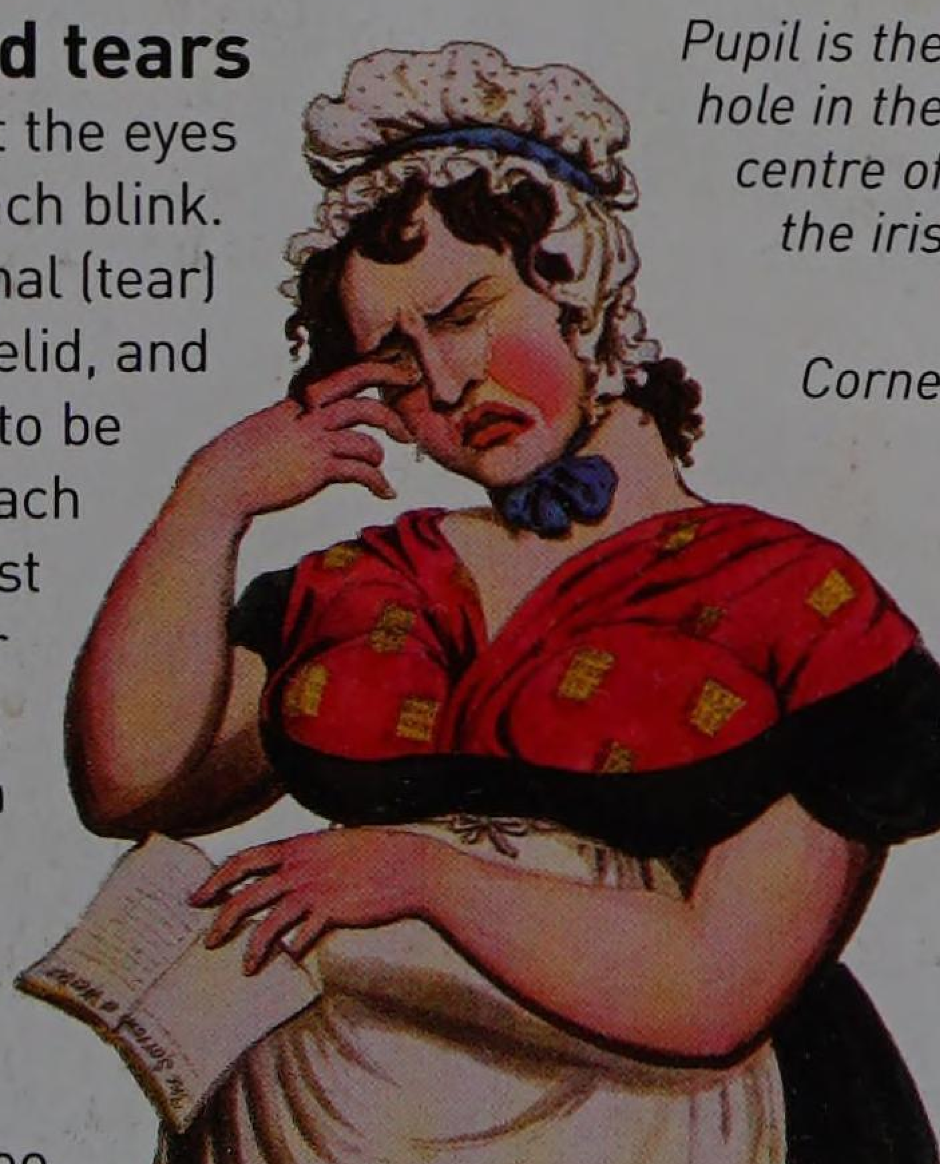


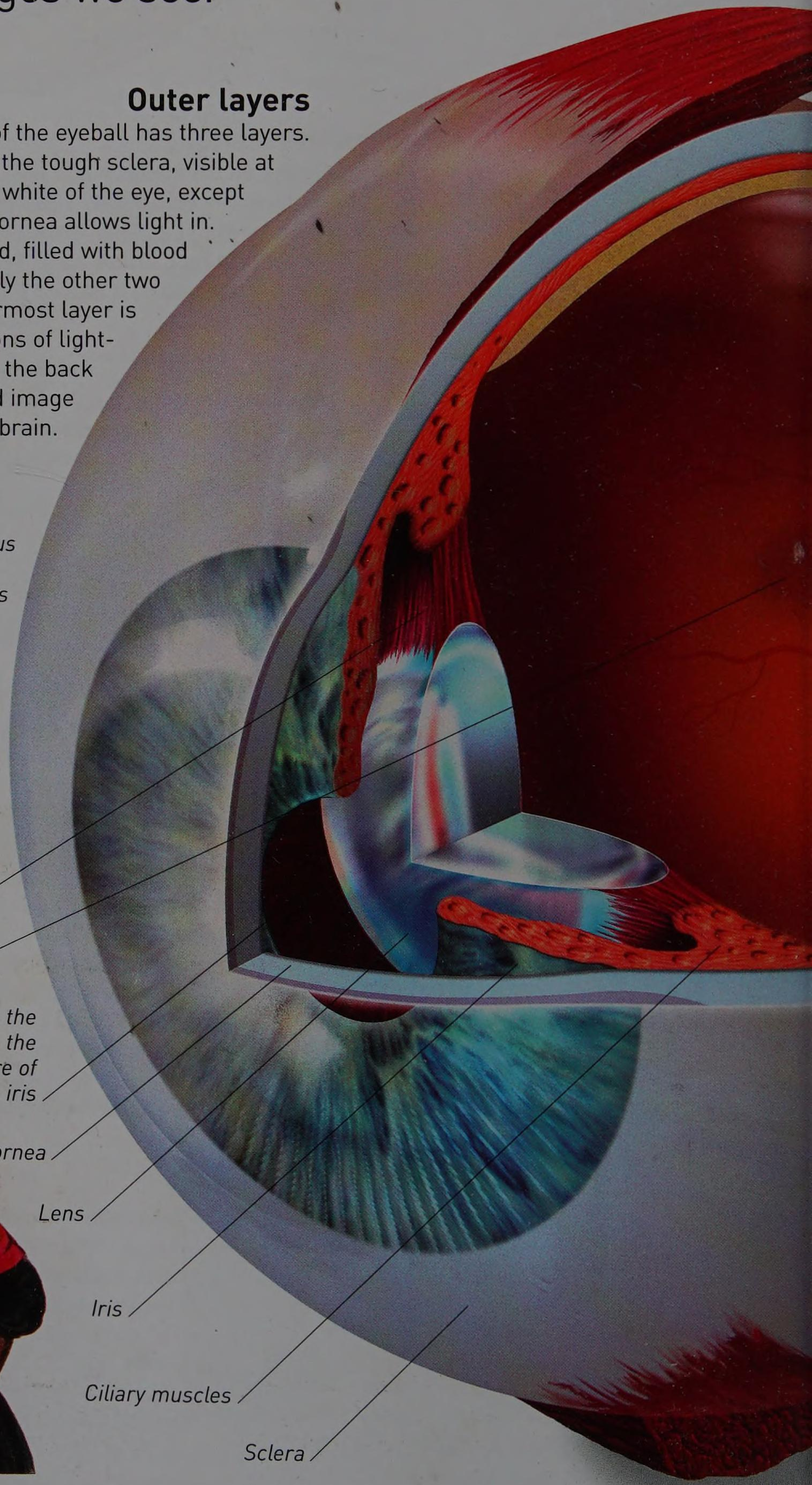
Moving the eye

Eyeballs automatically swivel in their sockets to follow moving objects. They also make tiny, jumping movements when scanning a face or the words on this page. Just six slim muscles produce all these movements.

Eyelids and tears

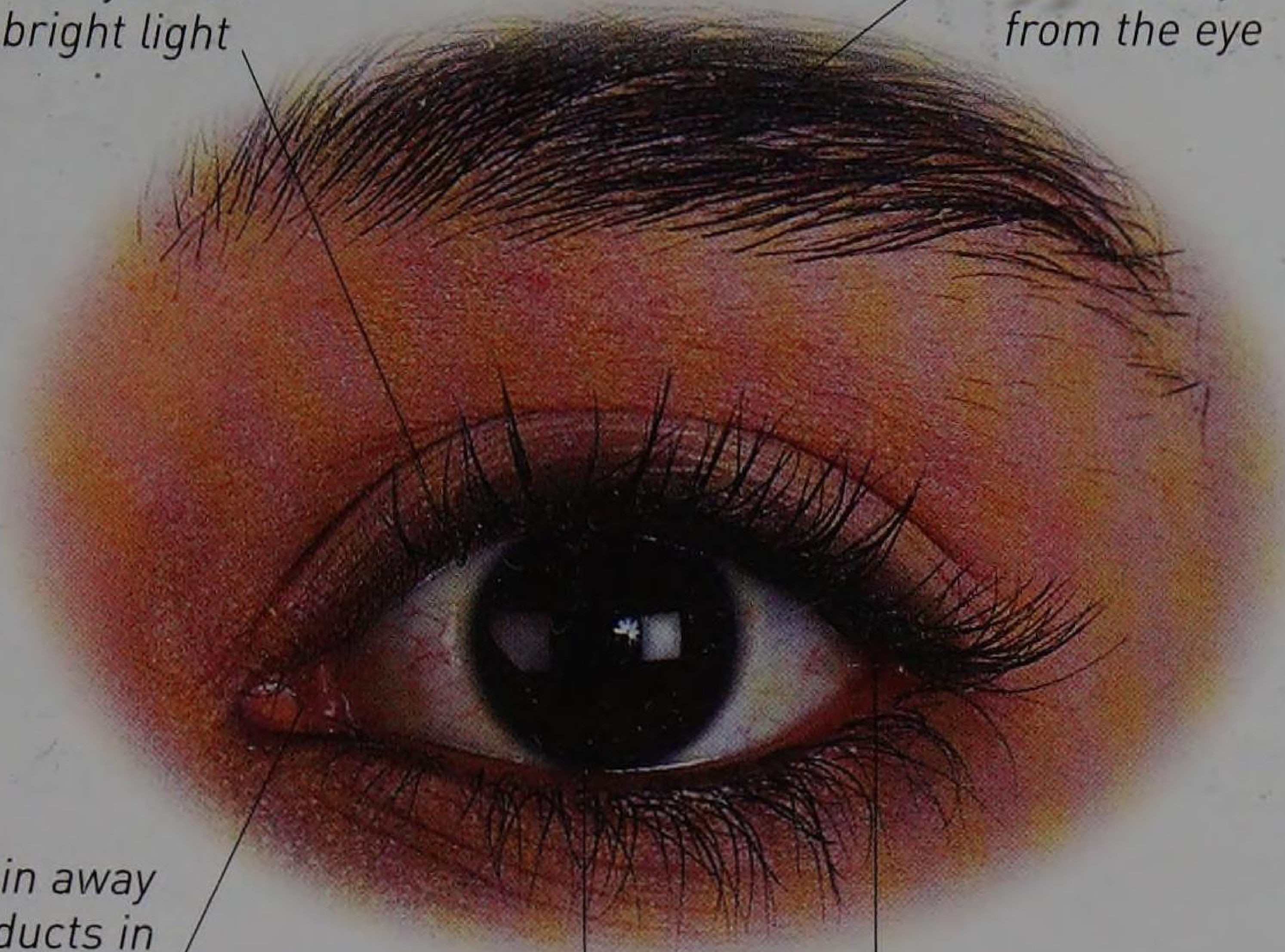
Soft, flexible eyelids protect the eyes and wash them with tears at each blink. Tears are produced by a lacrimal (tear) gland behind each upper eyelid, and flow along tiny ducts (tubes) to be spread over the eye with each blink. Tears keep the eye moist and wash away dust and other irritants. Used tear fluid drains away through two tiny holes in the eyelids near the nose, and along two ducts into the nose. That's why a good cry produces a runny nose too.

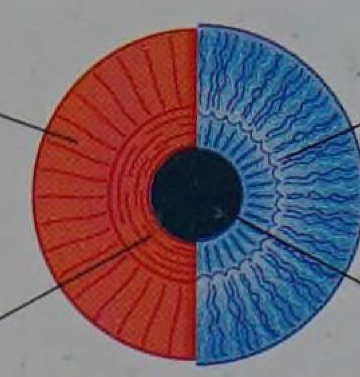


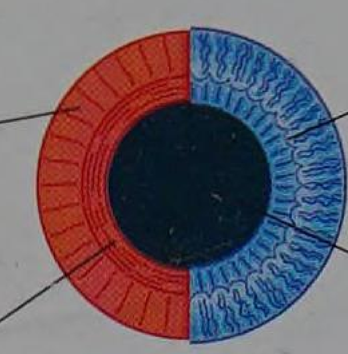


Eyes forward

Only one-sixth of an eyeball can be seen from the outside. The rest sits protected within a deep bowl of skull bone, the eye socket. Eyebrows, eyelids, and eyelashes protect the front of the eye by shading it from dust, sweat, and excessive light. The colour of the iris depends on the amount of the brown pigment melanin present.

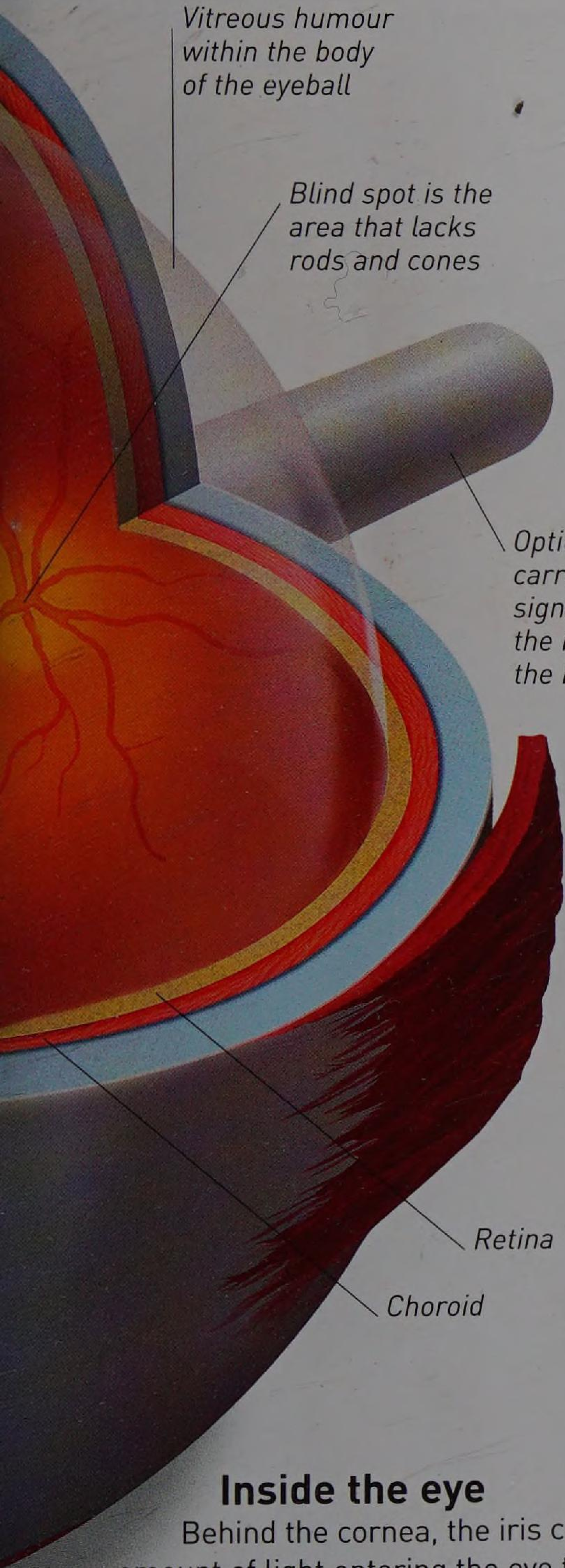






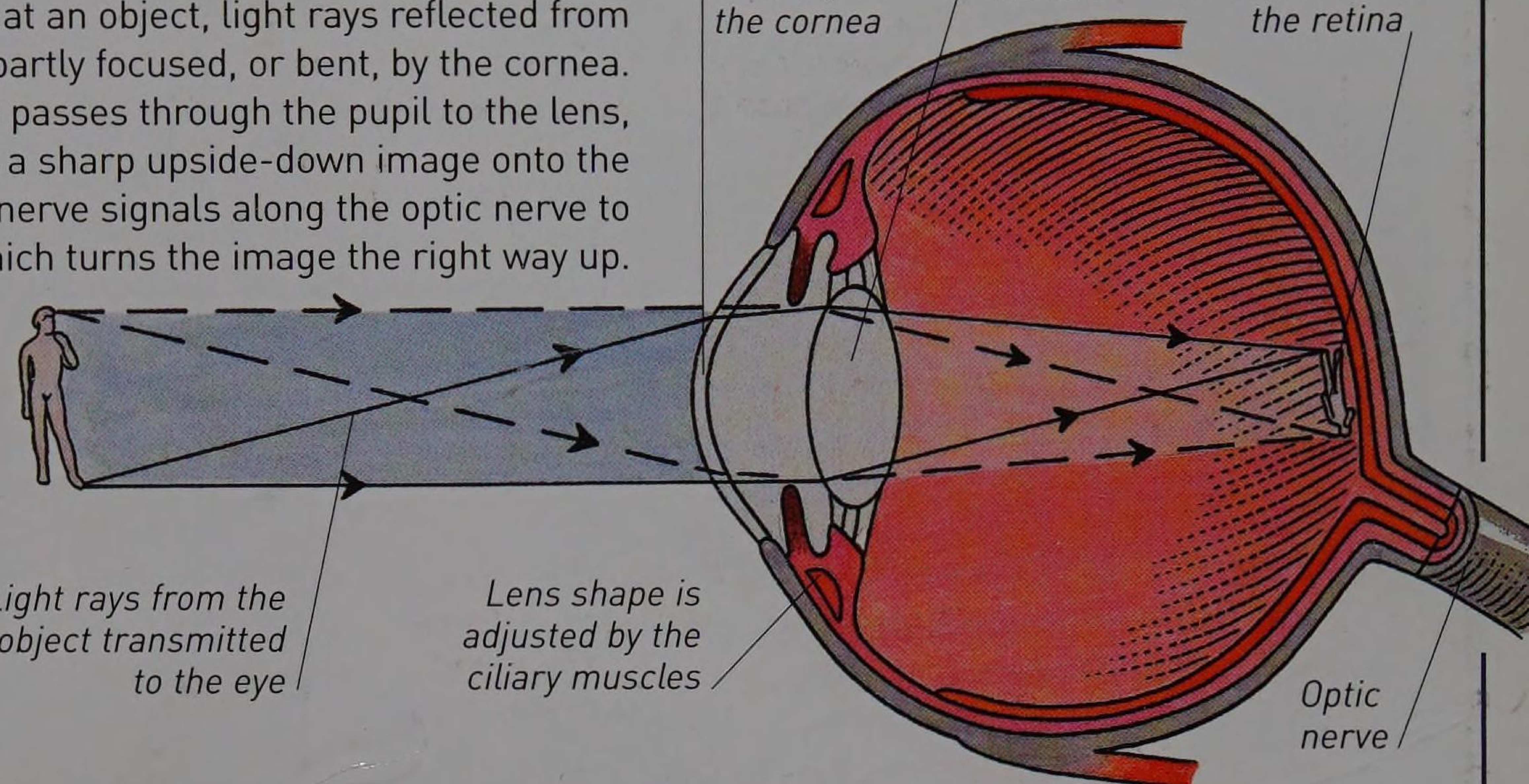
Pupil size

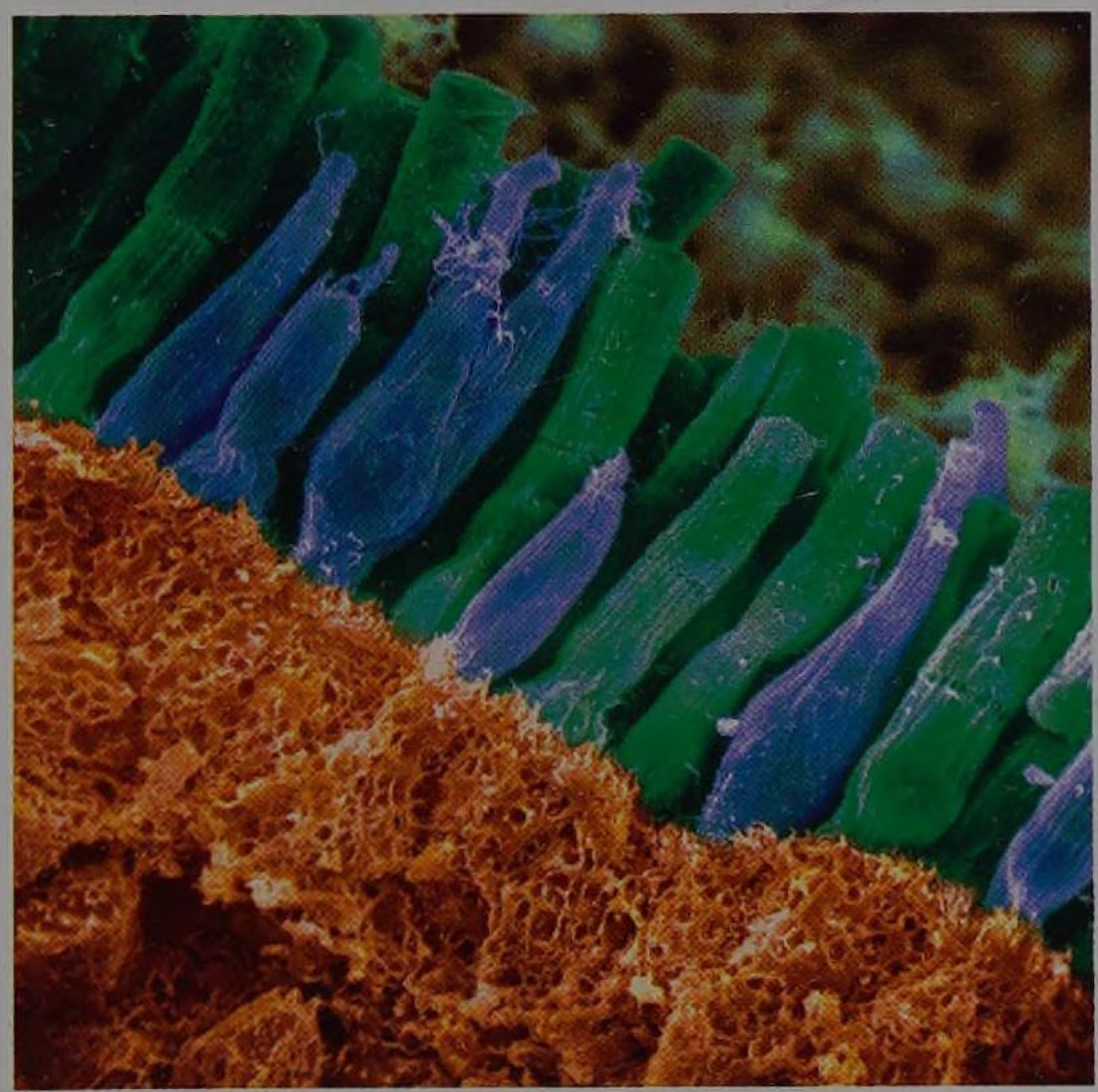
Muscle fibres (red) in the iris adjust the size of the pupil automatically. To avoid dazzle in bright light, circular fibres contract to make the pupil smaller. In dim light, to let more in, radial fibres contract, to enlarge the pupil.



Forming an image

When we look at an object, light rays reflected from that object are partly focused, or bent, by the cornea. The light then passes through the pupil to the lens, which projects a sharp upside-down image onto the retina. It sends nerve signals along the optic nerve to the brain, which turns the image the right way up.



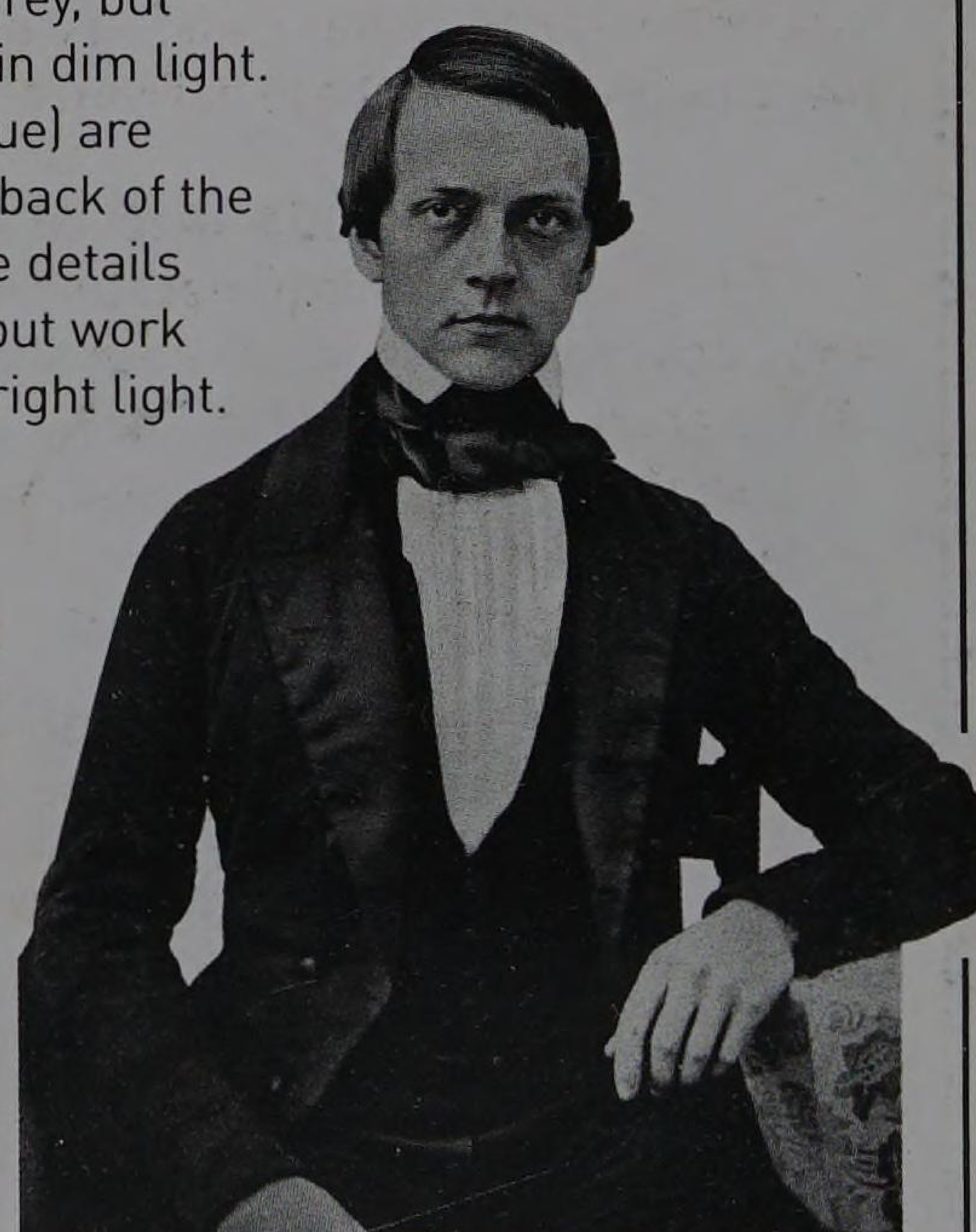


Rods and cones

The retina has two kinds of light-detecting cells. The rods (green) see only in shades of grey, but respond well in dim light. The cones (blue) are mainly at the back of the retina and see details and colours, but work well only in bright light.

Eye advances

German scientist Hermann von Helmholtz (1821–94) studied the mathematics of the eye in the *Handbook of Physiological Optics*. He also helped to invent the ophthalmoscope. Doctors use this light-and-lens device for close-up examinations of the eye's interior.



Inside the eye

Behind the cornea, the iris controls the amount of light entering the eye through the pupil. The space behind the lens is filled with clear, jelly-like vitreous humour. The most detailed images are produced where light falls on the fovea, a part of the retina that contains only cones (see above, right).

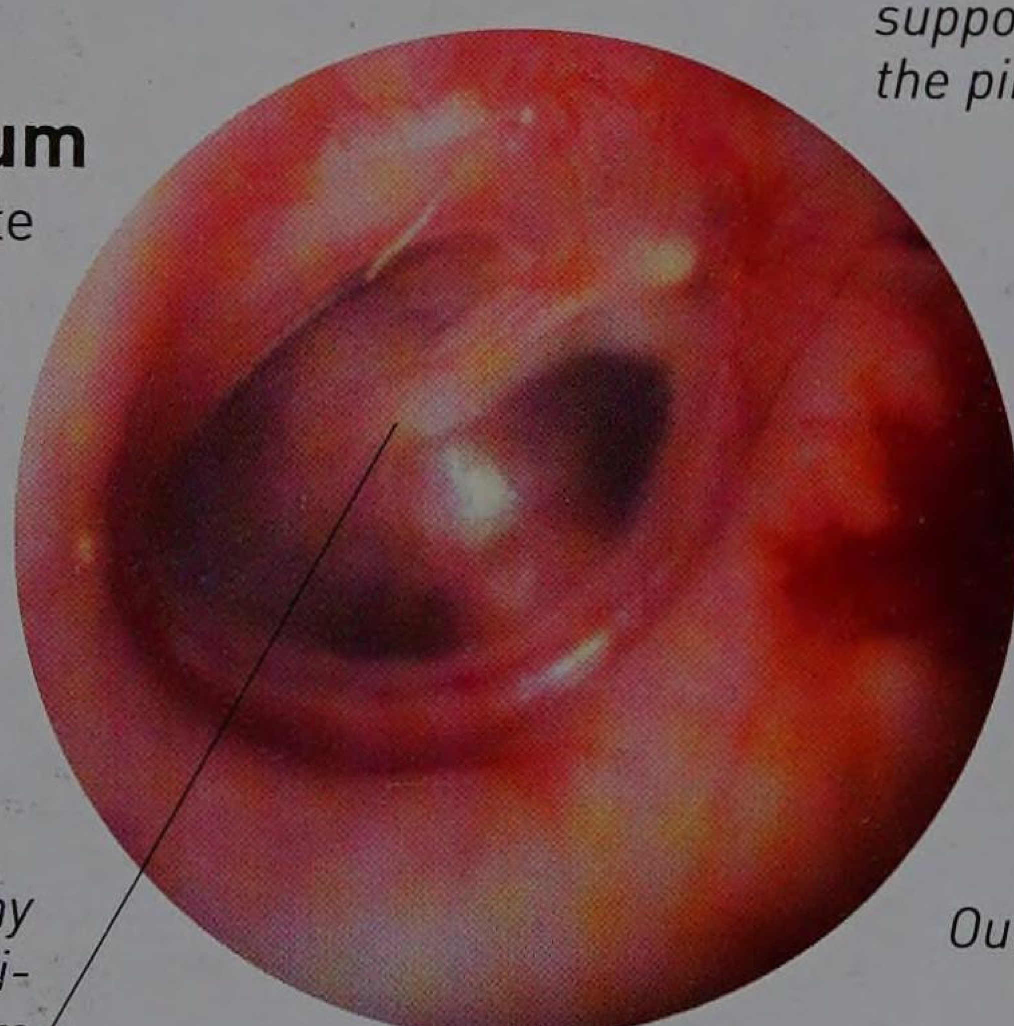
Ears and hearing

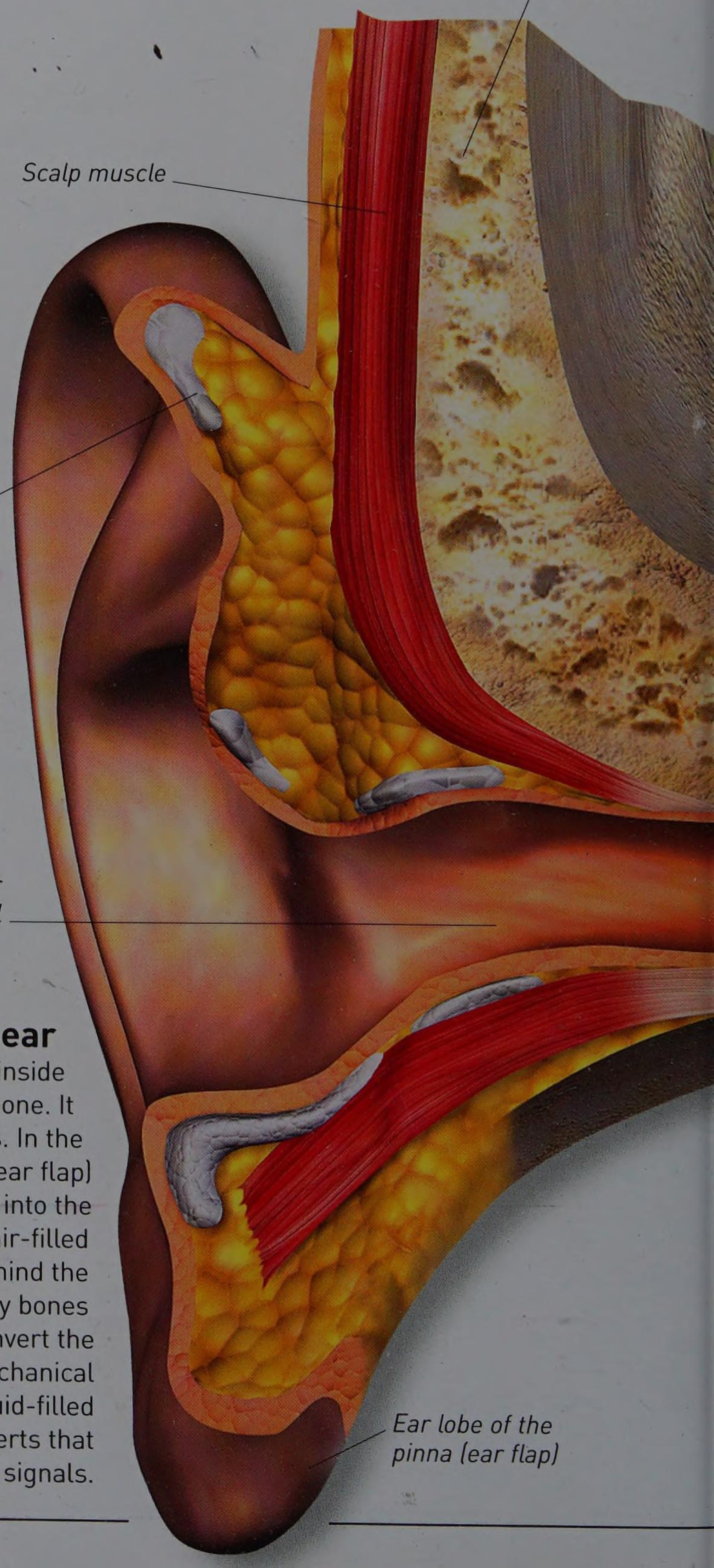
After sight, hearing provides the brain with the most information about the outside world. It enables us to work out the source, direction, and nature of sounds, and to communicate with each other. Our ears detect waves of pressure, called sound waves, which travel through the air from a vibrating sound source. The ears turn these waves into nerve signals, which the brain interprets as sounds that range from loud to quiet and from high pitched to low.

The mind's ear
German composer and pianist Ludwig van Beethoven (1770–1827) went deaf but continued to compose masterpieces by imagining the notes in his head.

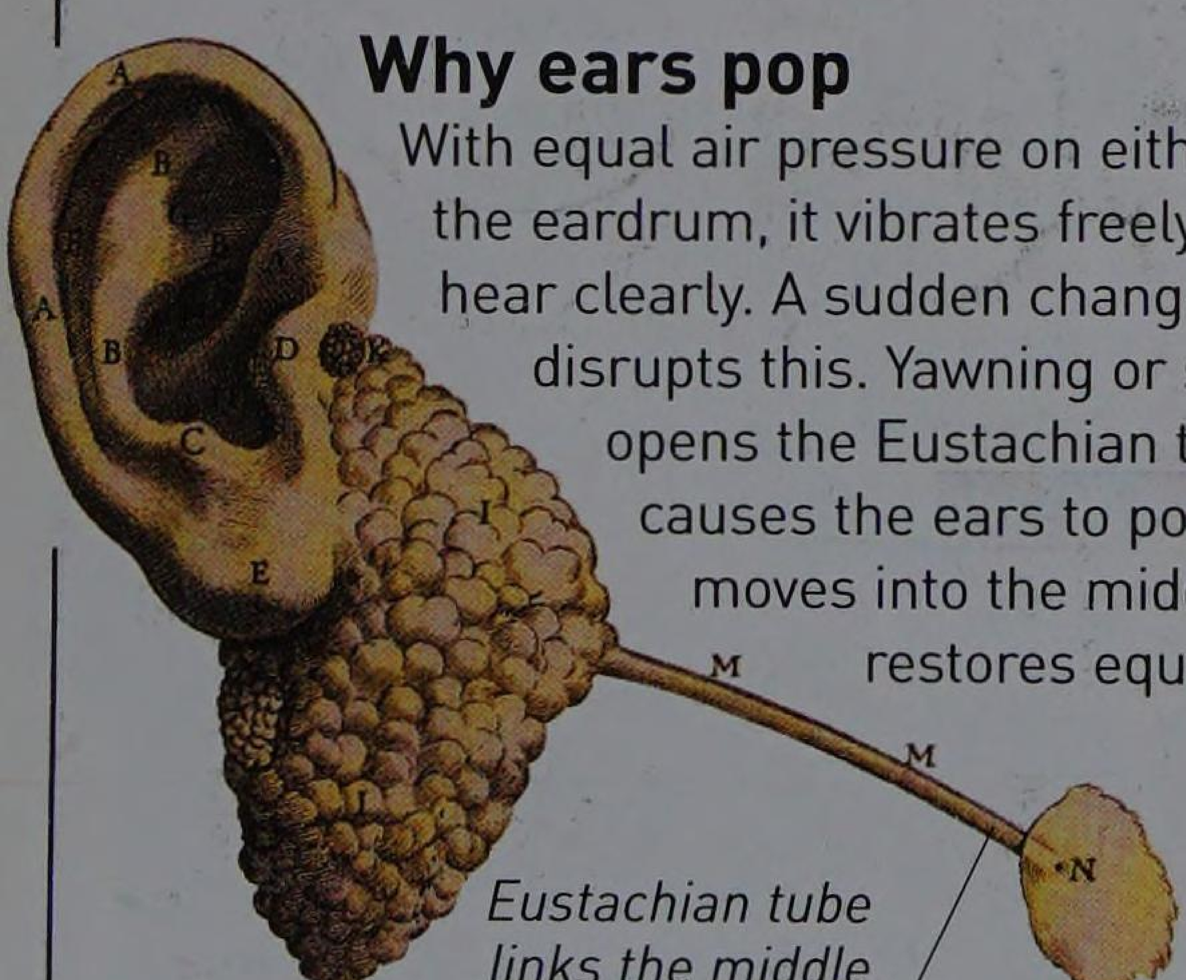
Ear pioneer
The Examination of the Organ of Hearing, published in 1562, was probably the first major work devoted to ears. Its author was the Italian Bartolomeo Eustachio (c. 1520–74), a professor of anatomy in Rome. His name lives on in the Eustachian tube that he discovered, which connects the middle ear to the back of the throat.

The eardrum
The eardrum is a taut, delicate membrane, like the stretched skin on a drum, that vibrates when sound waves enter the ear. It separates the outer ear from the middle ear. Doctors can examine the eardrum through a medical instrument called an otoscope.



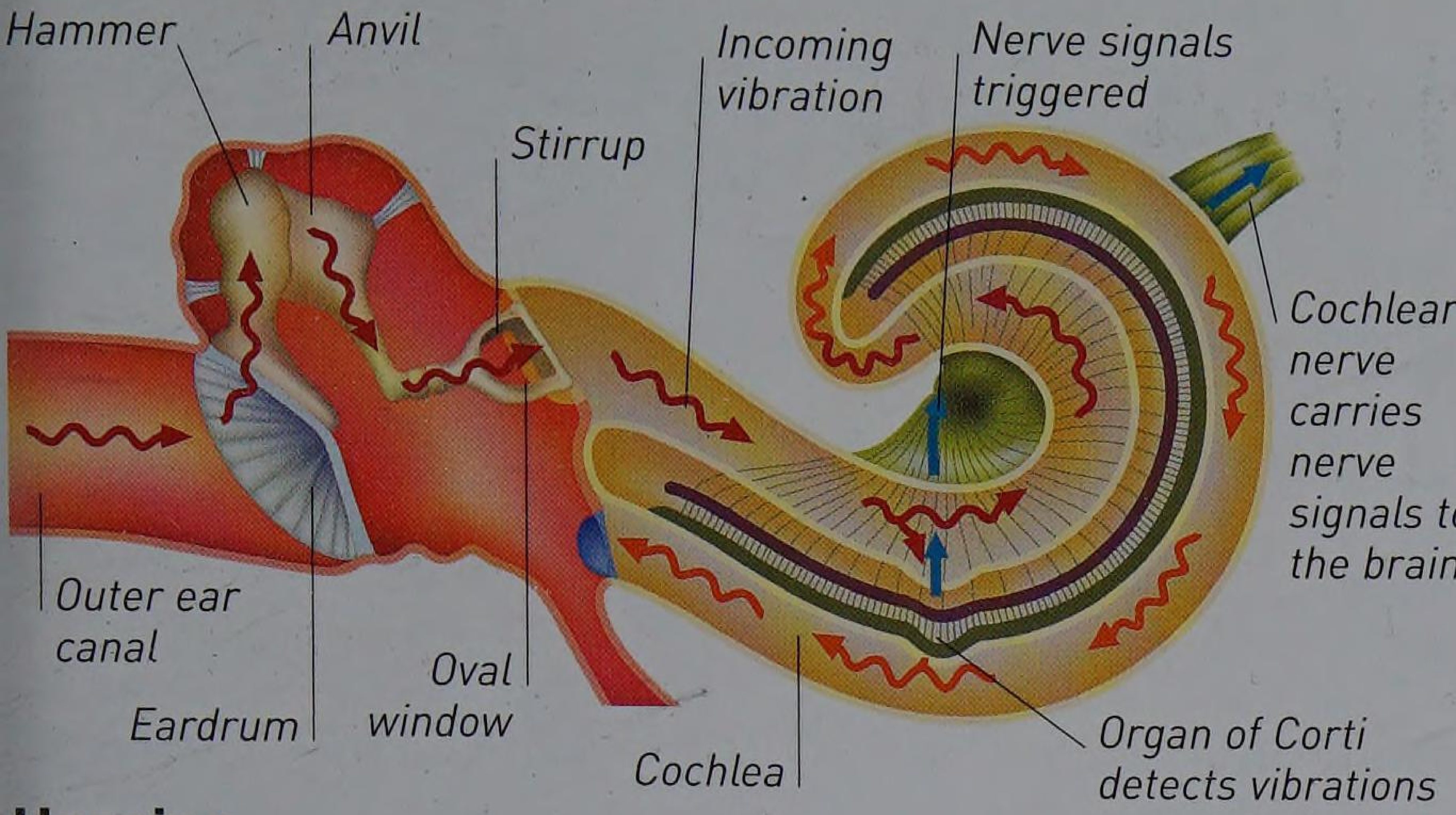


Why ears pop
With equal air pressure on either side of the eardrum, it vibrates freely and so we hear clearly. A sudden change in pressure disrupts this. Yawning or swallowing opens the Eustachian tube and causes the ears to pop, as air moves into the middle ear and restores equal pressures.



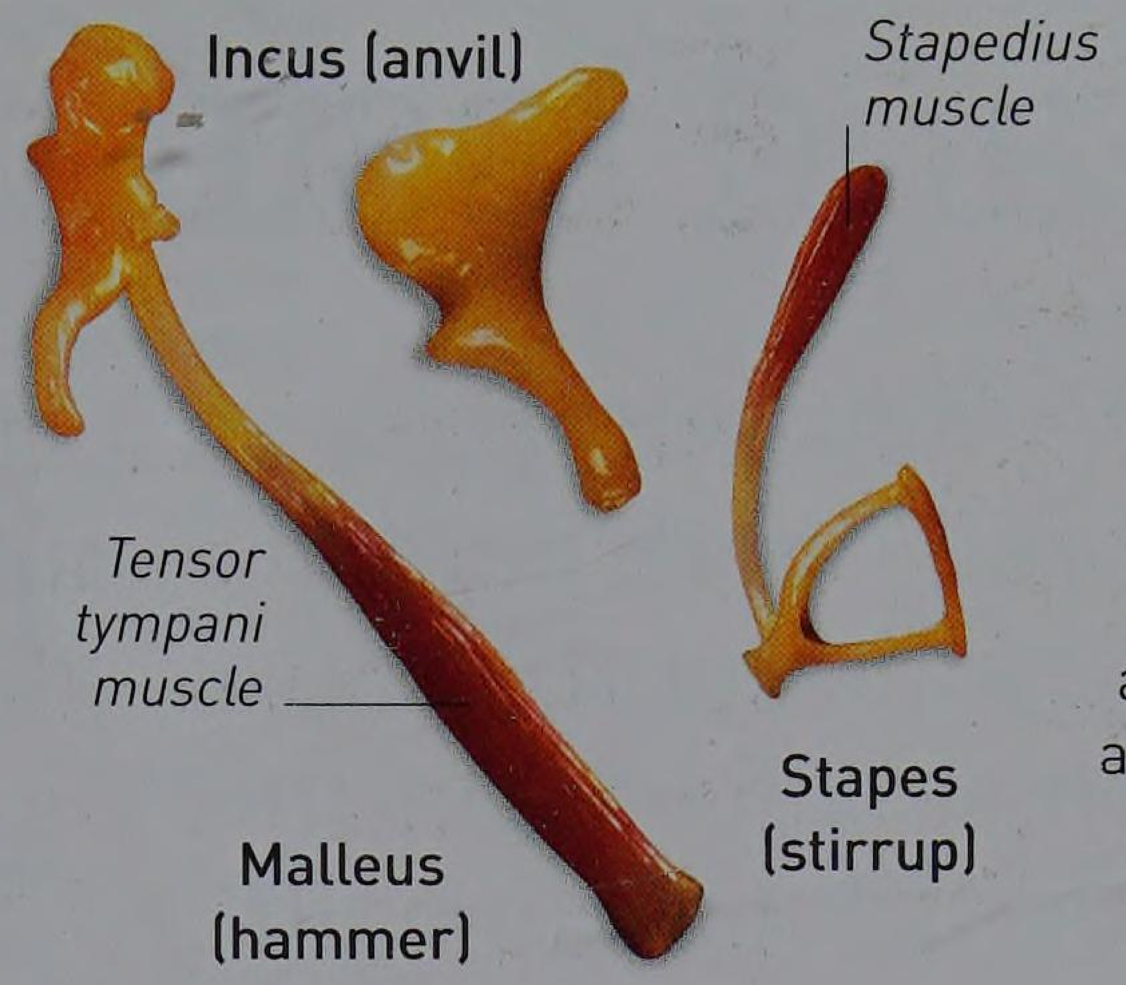
18th-century drawing of the ear

Inside the ear
Most of the ear lies inside the skull's temporal bone. It has three main parts. In the outer ear, the pinna (ear flap) directs sound waves into the ear canal. In the air-filled middle ear, behind the eardrum, three tiny bones called ossicles convert the sound waves into mechanical movement. The fluid-filled inner ear converts that movement into nerve signals.



Hearing

Sound waves funnelled into the ear canal strike the eardrum, making it vibrate. This makes the three ossicles move back and forth. The stirrup pushes and pulls the flexible oval window like a piston. This sets up vibrations in the fluid filling the cochlea. Inside the cochlea, sound-detecting hair cells turn the vibrations into nerve signals. These pass along the cochlear nerve to the hearing area of the brain.

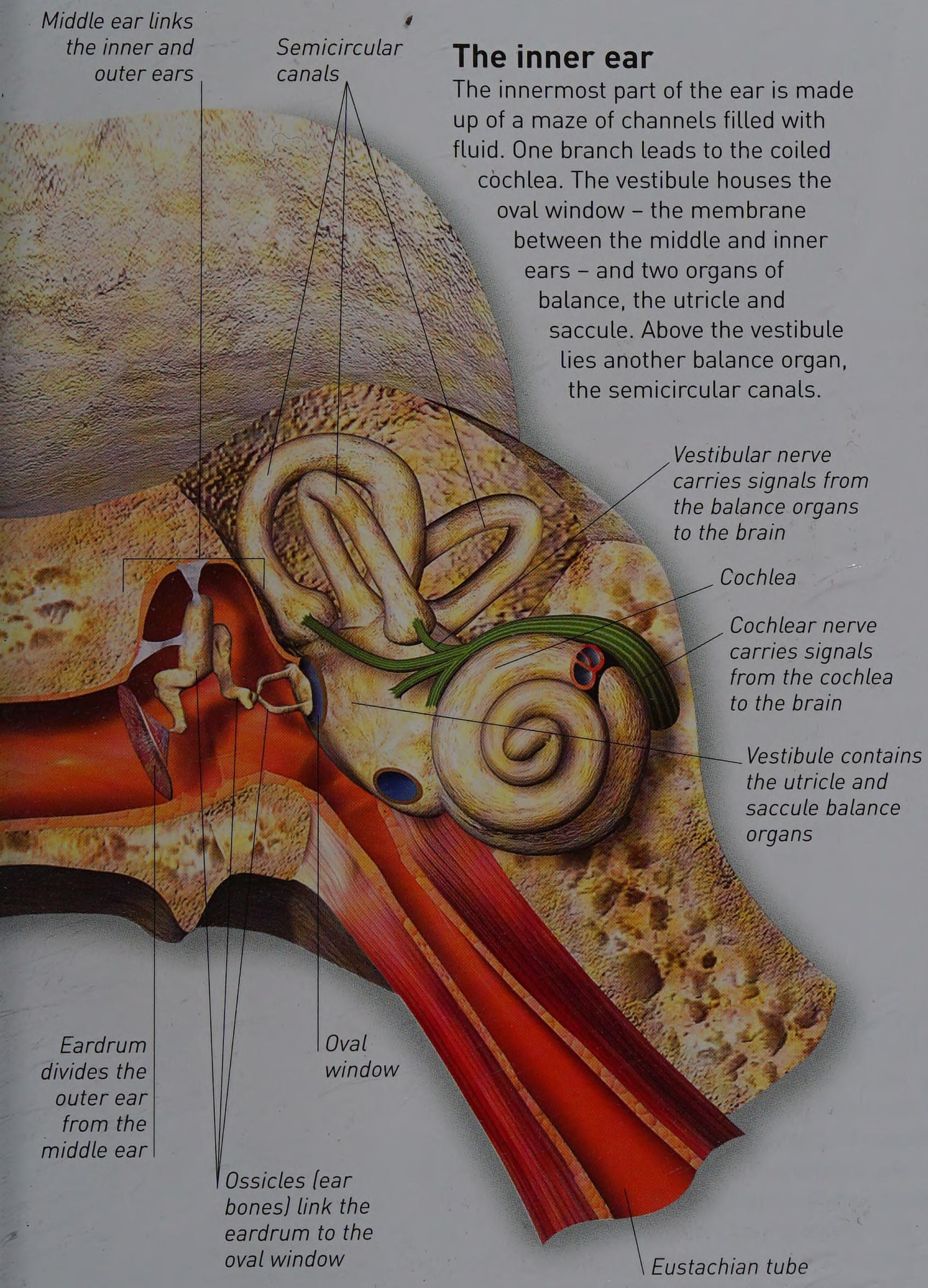


Ossicles

The ossicles are the smallest bones in the body. They get their Latin names from their shapes. Attached to the bones are two of the body's smallest muscles. If a very loud sound reaches the eardrum, they contract to reduce the intense vibrations that would damage the inner ear.

Smallest bones

The ossicles are tiny. The malleus (hammer) above is actual size. It is about 8 mm (0.3 in) long, almost twice the size of the stapes (stirrup).

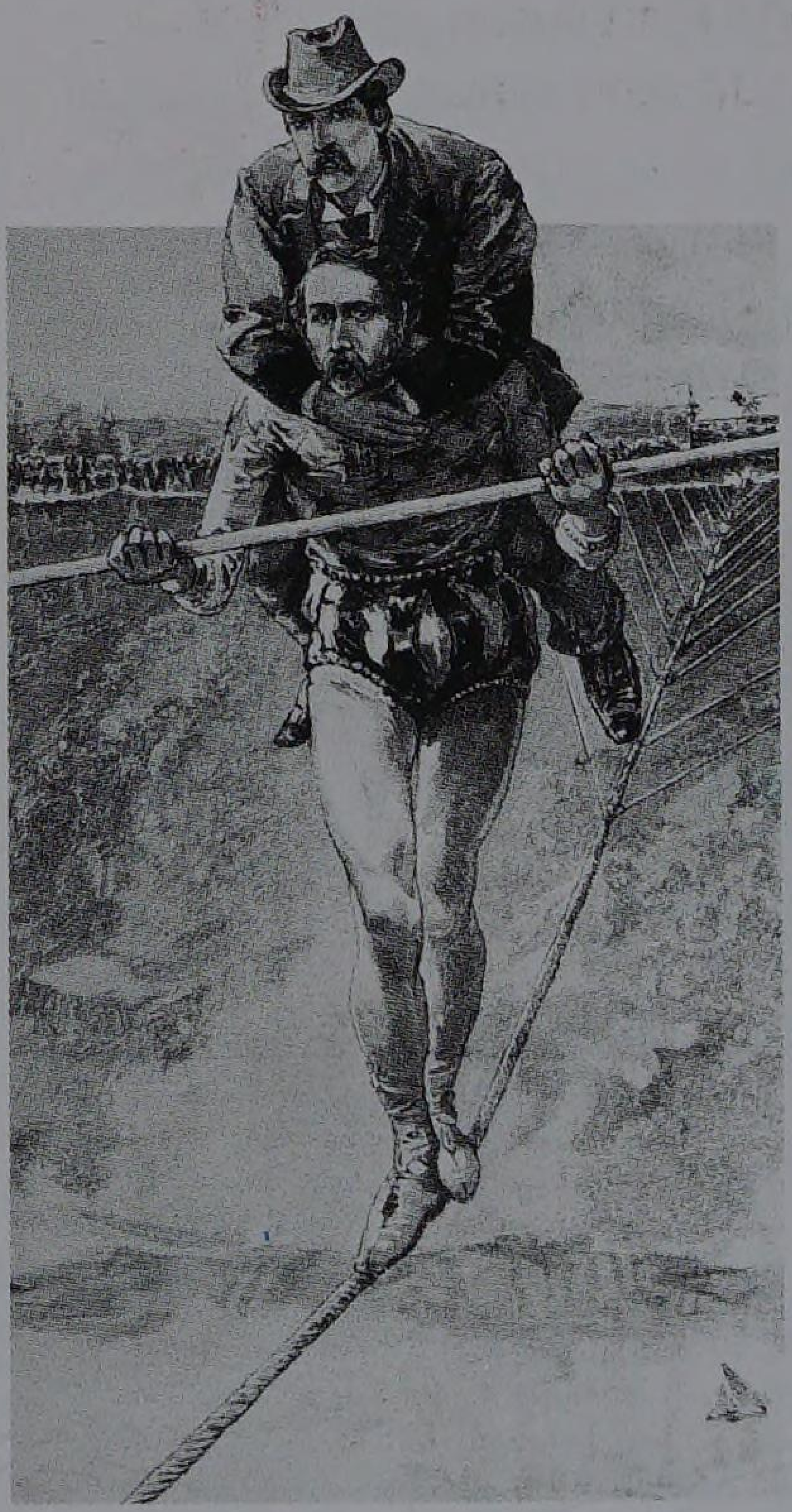


The inner ear

The innermost part of the ear is made up of a maze of channels filled with fluid. One branch leads to the coiled cochlea. The vestibule houses the oval window – the membrane between the middle and inner ears – and two organs of balance, the utricle and saccule. Above the vestibule lies another balance organ, the semicircular canals.

Inside the organ of Corti

When sound vibrations pass through the cochlea's fluid, hair cells (red) move up and down. This squashes them, causing hair cells to send signals to the brain. They do the same in the balance organs.



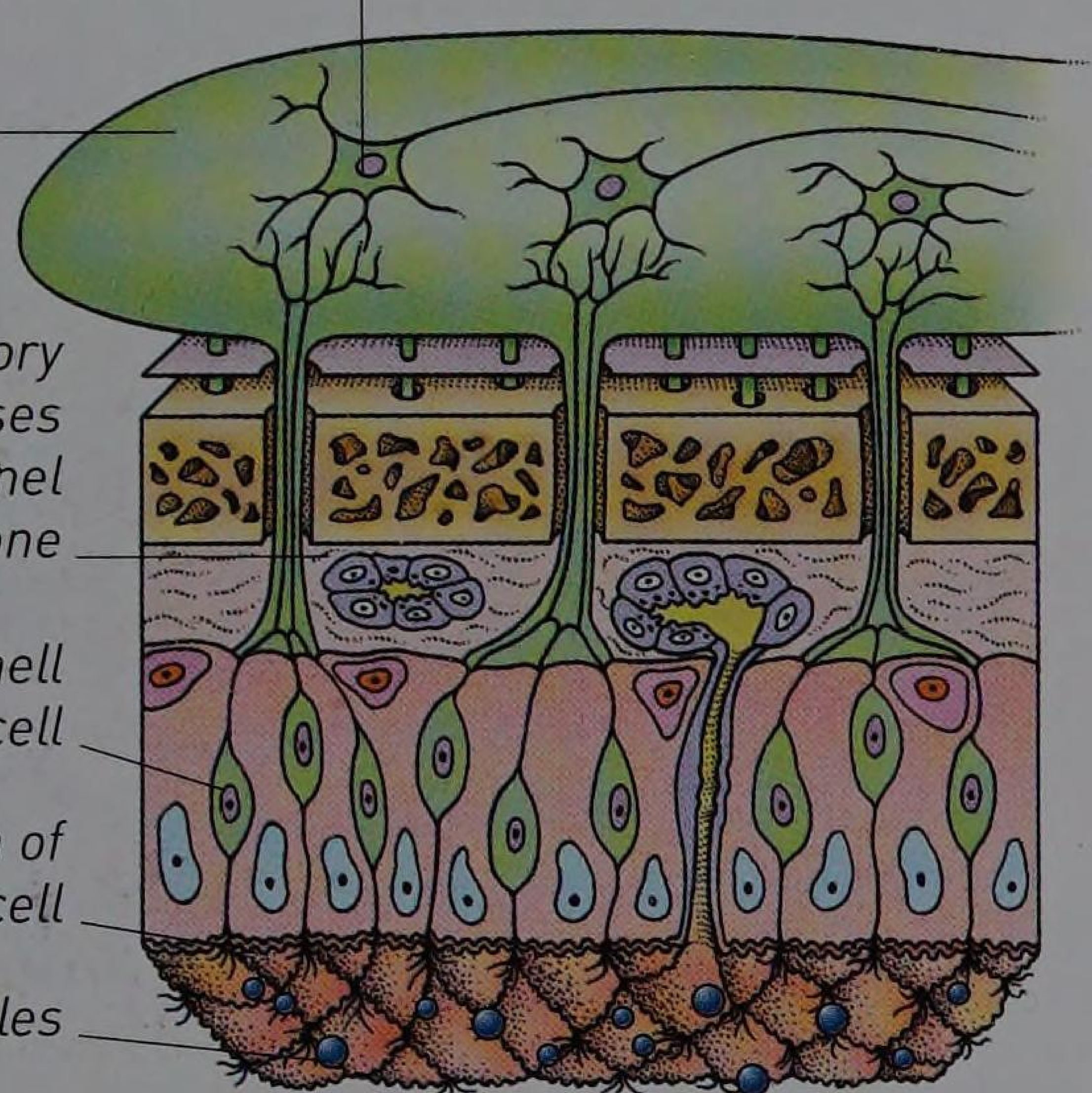
Balancing act

The inner ear houses the fluid-filled organs that help the body keep balance. The three semicircular canals detect rotation of the head in any direction. The utricle and saccule detect when the head – and body – accelerates. These balance organs constantly update the brain, so that it can keep the body upright.

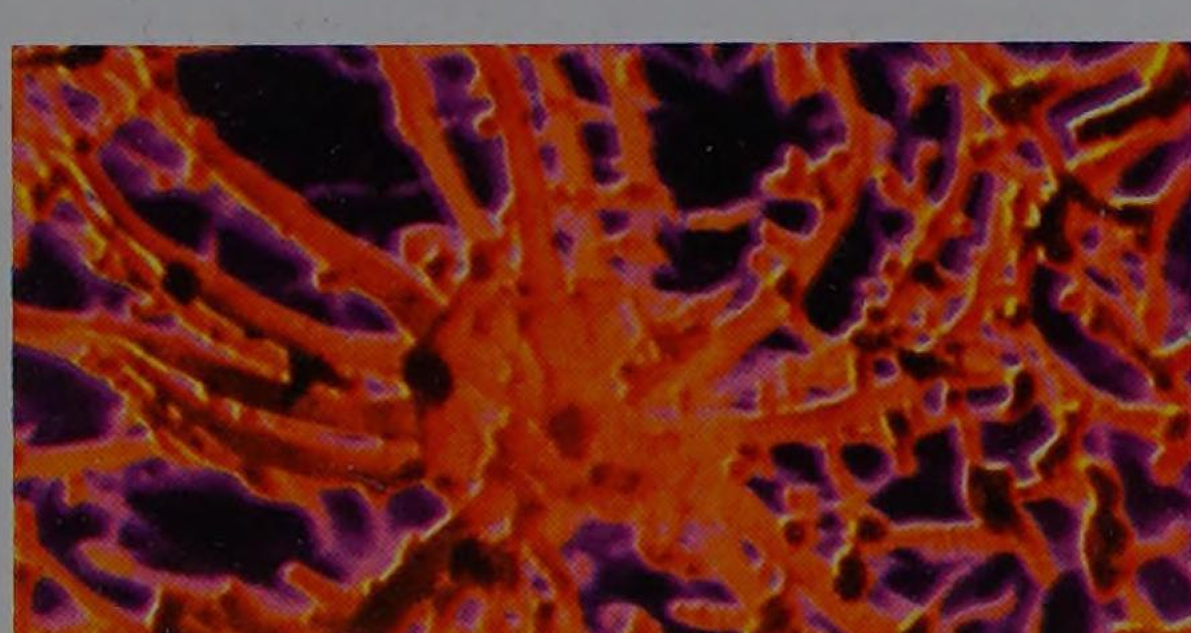
Smell and taste

The senses of smell and taste are closely linked – both detect chemicals. Taste receptors on the tongue detect substances in drink and food. Olfactory (smell) receptors in the nasal cavity pick up odour molecules in air. The two senses enable us to detect all kinds of scents and flavours, good and bad.

Bad air
For centuries, physicians thought diseases were carried by foul-smelling air. This 14th-century physician holds aromatic herbs to his nose to avoid catching his patient's illness.

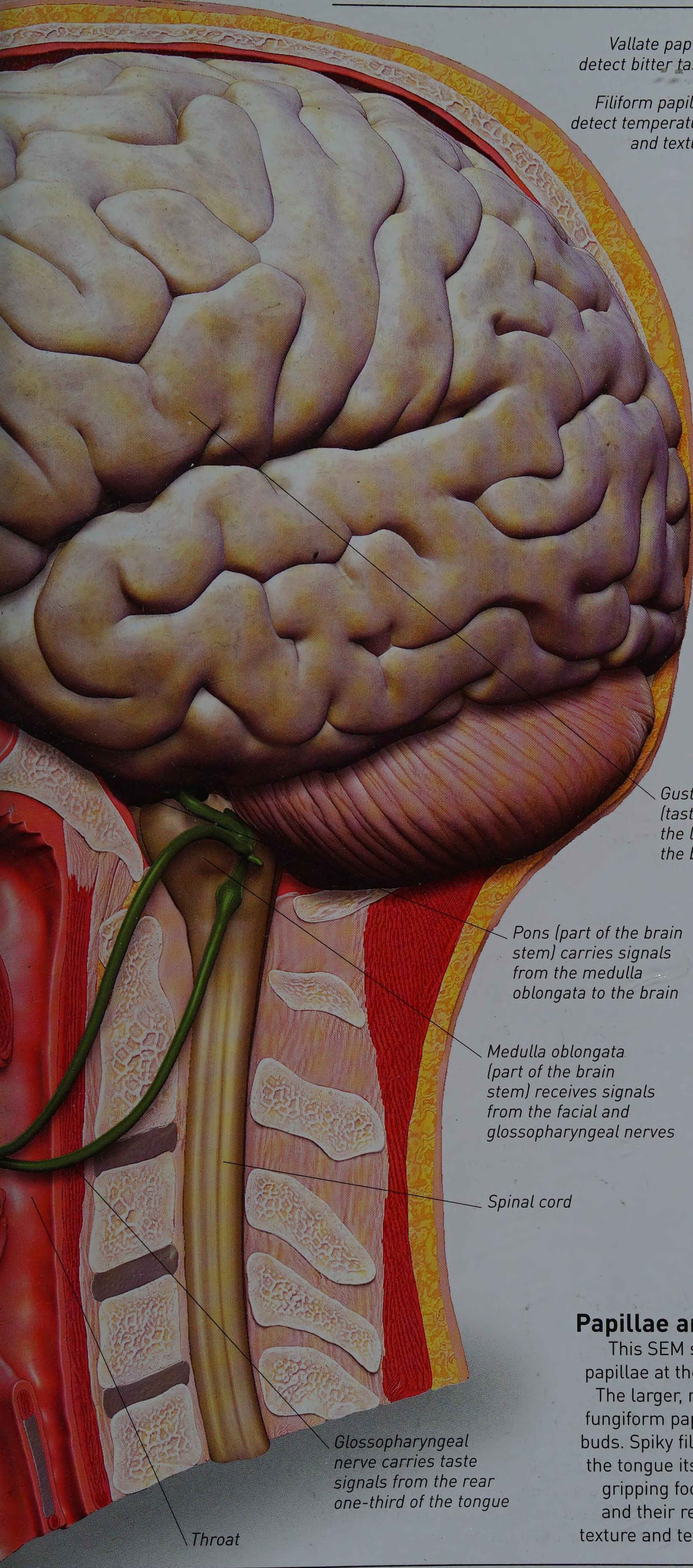


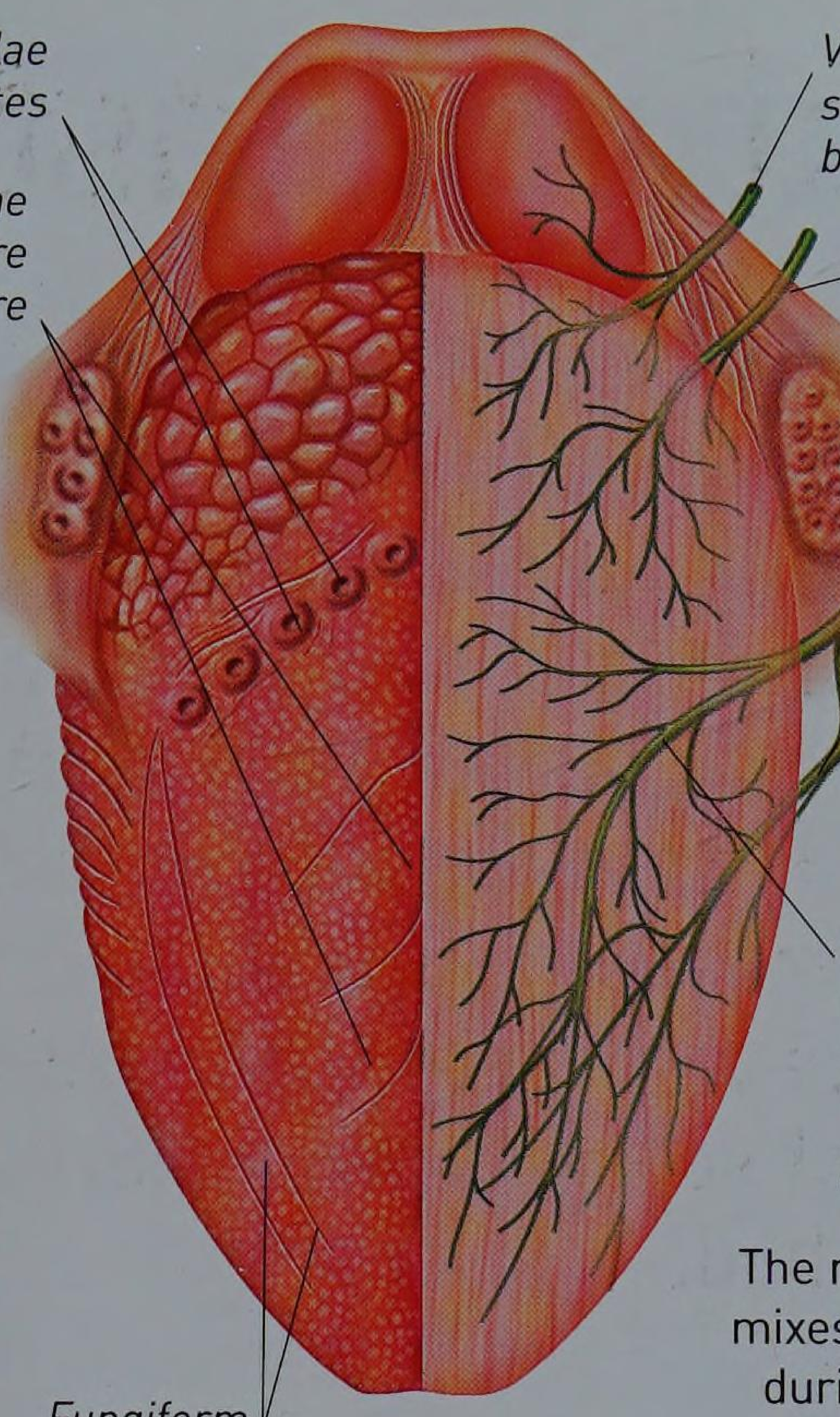
Cross-section inside the nose
The nasal cavity's lining (pink) contains thousands of smell receptor cells The cells' hair-like cilia project into the watery mucus of the nasal lining. They detect odour molecules in the air and relay signals to the olfactory nerve, the olfactory bulb, and the brain.



Odour detectors
Odour molecules dissolve in mucus and bind to these cilia, triggering the receptor cells to send signals to the brain. Olfactory receptors can distinguish between 10,000 smells.

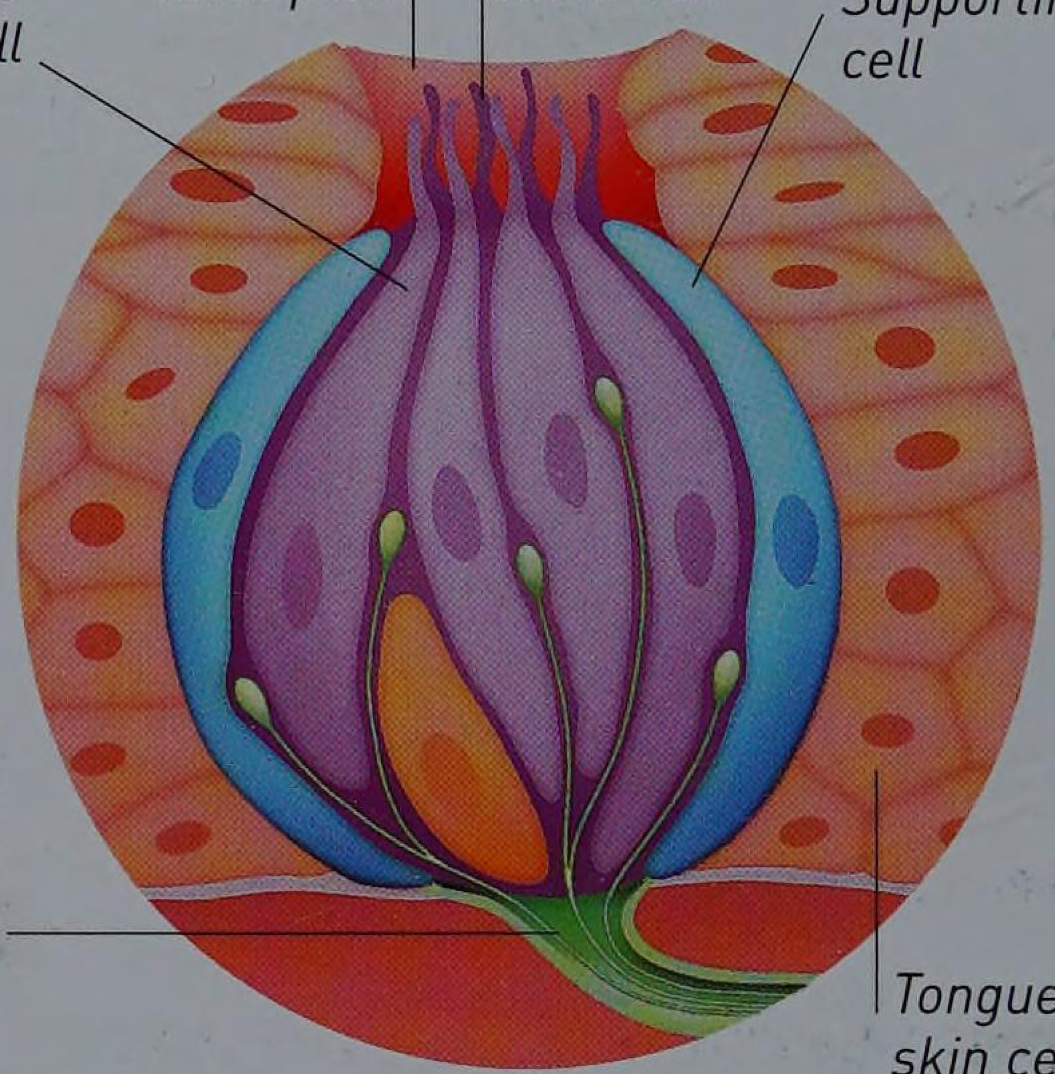
Smell and taste pathways
A cross-section through the head shows the routes taken by nerve signals from smell receptors in the nose, and from taste buds in the tongue. In the nasal cavity, branches of the olfactory nerve send signals to the olfactory bulb, which carries the signals to the areas at the front of the brain that identify smells. Taste signals from the front and back of the tongue travel along separate nerves to the brain stem's medulla oblongata. From here they are sent to the area of the brain where tastes are recognized.





Taste organ

The muscular tongue mixes and tastes food during chewing. It is covered with pimple-like papillae of different types. These make the tongue sensitive to taste and also to touch and temperature.



Taste buds

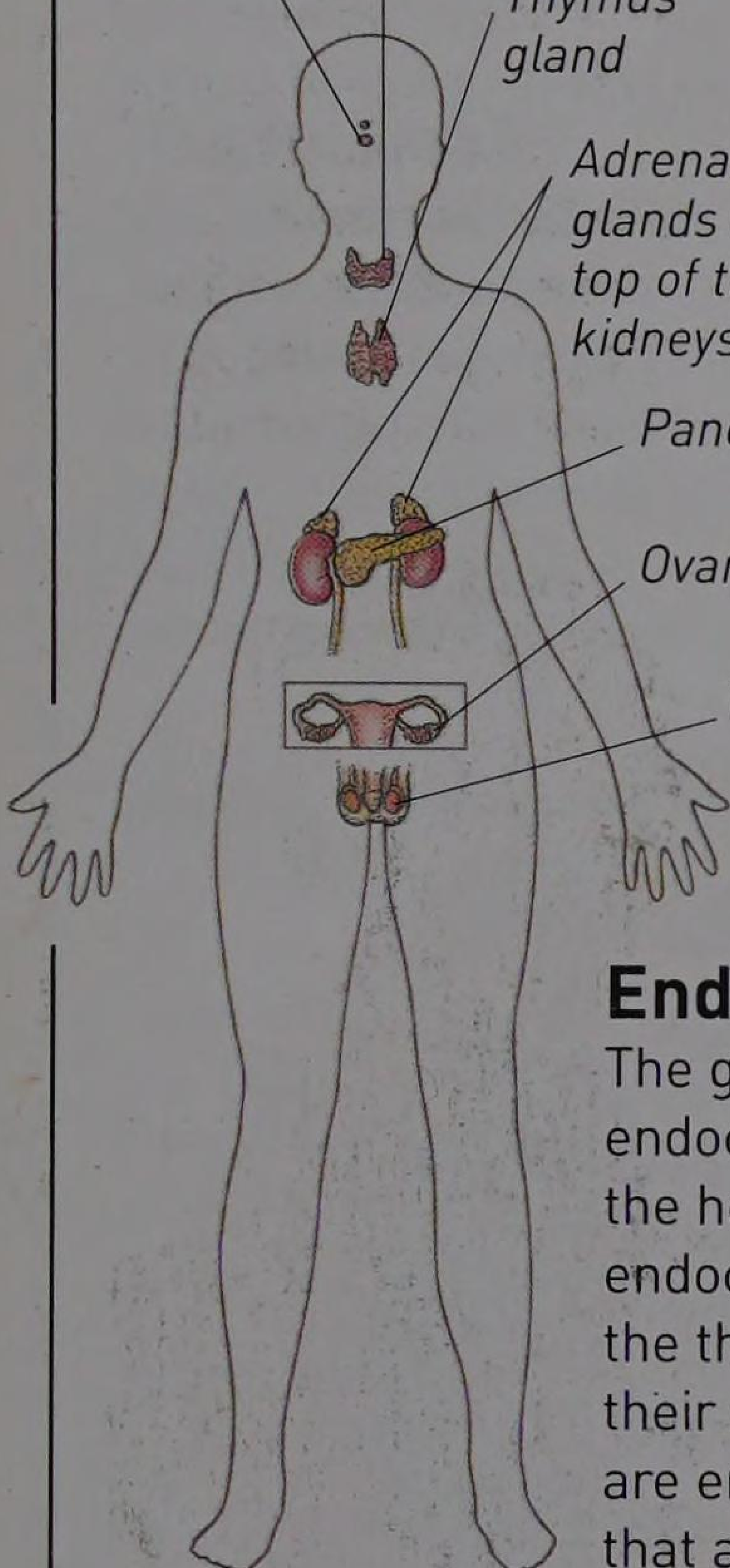
There are around 10,000 taste buds on the tongue, located on certain papillae. Taste molecules dissolve in saliva during chewing and pass into a taste bud through a pore. Here the hairs at the top of the taste receptor cells detect one of five tastes – sweet, sour, salty, bitter, or umami (savoury).

Papillae and taste buds

This SEM shows two types of papillae at the tip of the tongue. The larger, mushroom-shaped fungiform papillae contain taste buds. Spiky filiform papillae give the tongue its rough surface for gripping food during chewing, and their receptors detect the texture and temperature of food.

Hormones

A second control system works alongside the brain and nerve network. The endocrine system is a collection of glands that release chemical messengers, or hormones, into the bloodstream. They control body processes, such as growth and reproduction, by targeting specific body cells and altering their chemical activities. Located in the brain, the hypothalamus links the two control systems.



Endocrine system
The glands that make up the endocrine system lie inside the head and torso. Some endocrine glands, such as the thyroid, are organs in their own right. Other glands are embedded in an organ that also has other functions.

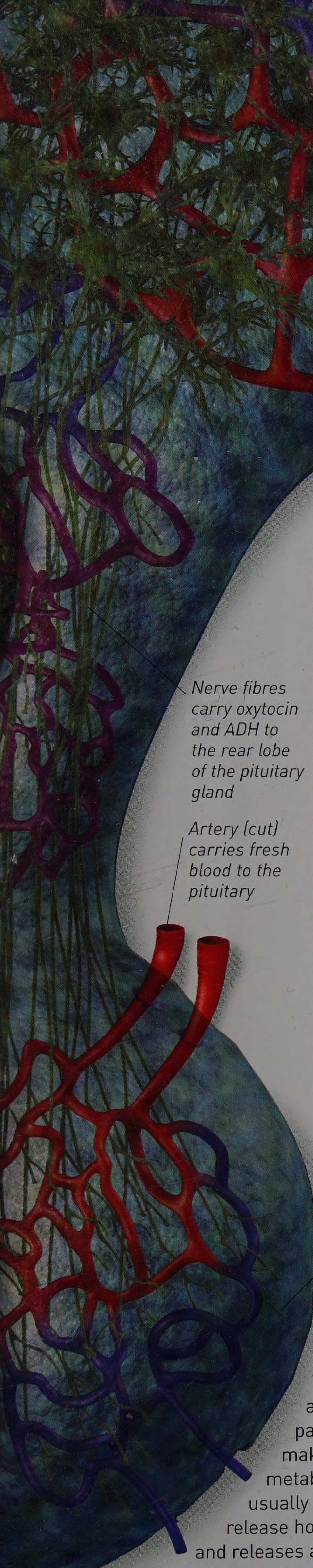
Thyroid gland
This gland makes two main hormones. Thyroxine targets most body cells and increases their metabolism (chemical processes) to stimulate growth and development. Calcitonin triggers the bones' uptake of calcium from blood.

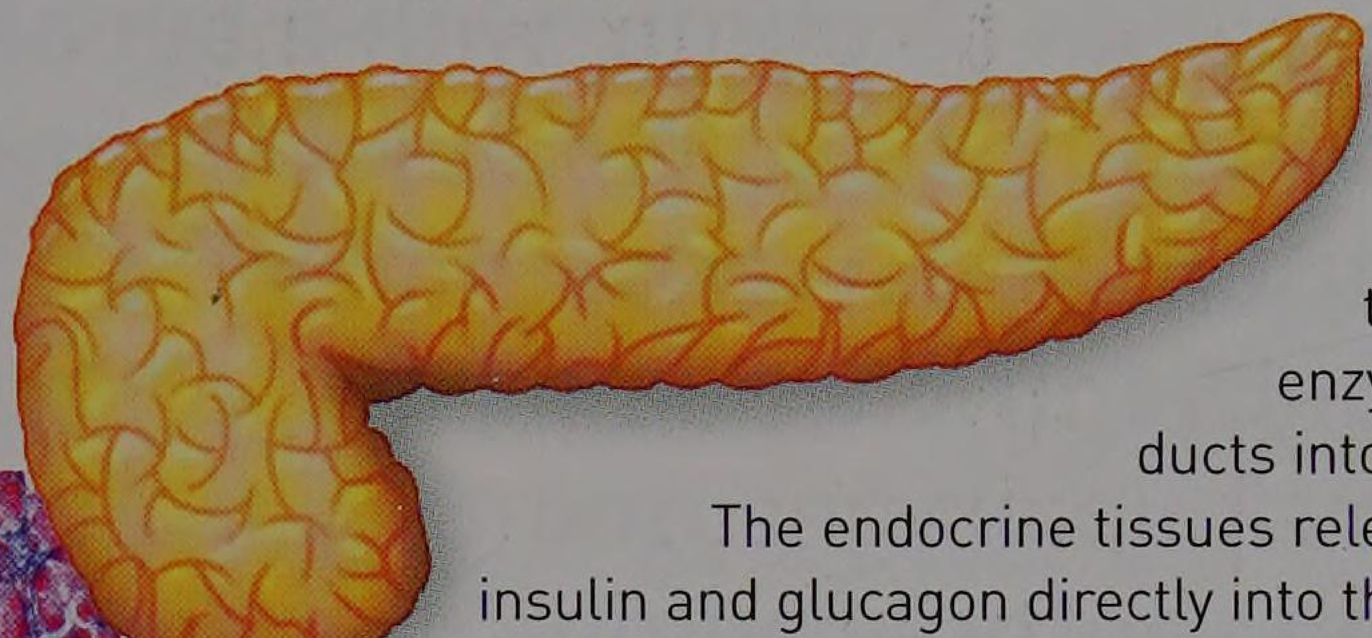
Fight or flight
The hormone adrenaline prepares the body to fight or flee in the face of danger. It does this by rapidly boosting heart and breathing rates and diverting blood and extra glucose (sugar) to the muscles.

Adrenal glands
The two adrenal glands on the kidneys produce corticosteroids, hormones that regulate the levels of salt and water in the blood, speed up the body's metabolism, and deal with stress. The medulla inside each kidney releases adrenaline, the hormone that prepares the body to deal with threats (see left).

Hypothalamus

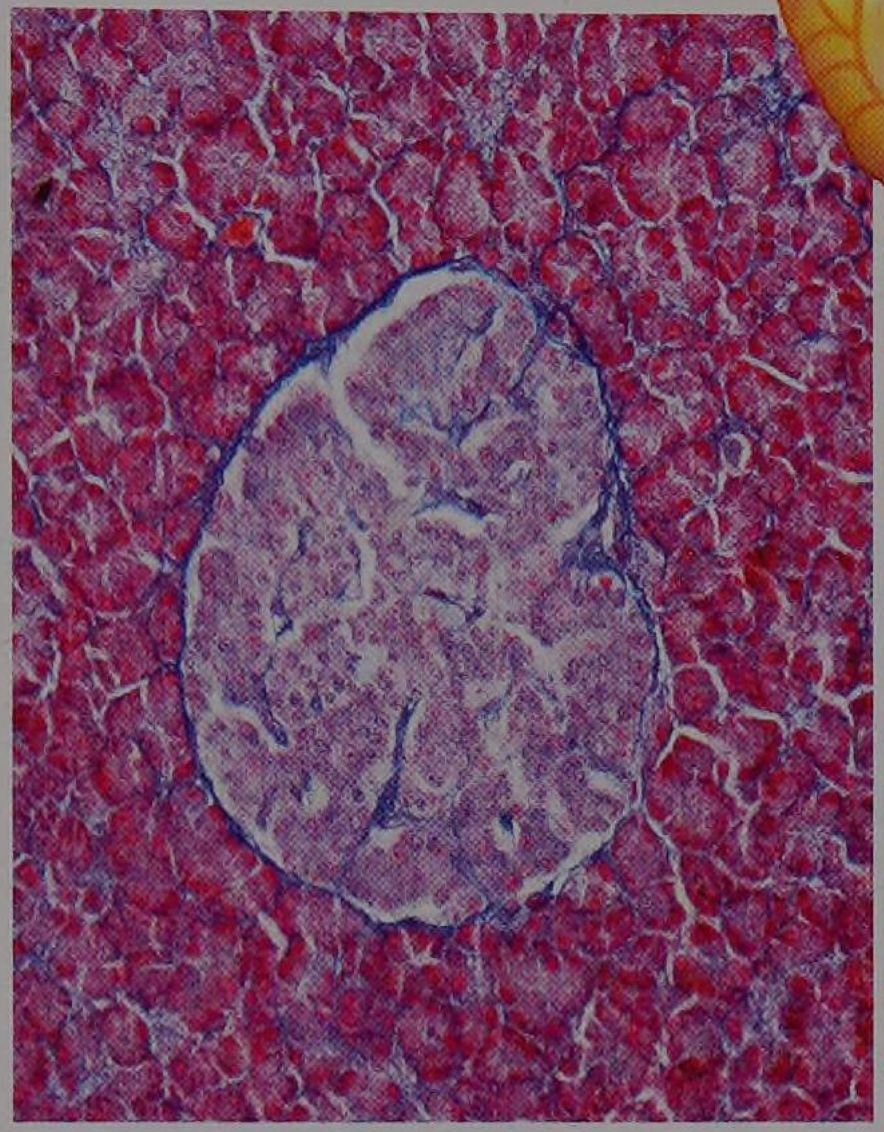
The almond-sized hypothalamus at the base of the brain controls a range of body activities, sometimes through the pituitary gland. Nerve cells in the rear of the hypothalamus produce regulating hormones that travel in the bloodstream to the front lobe of the pituitary, to stimulate the release of pituitary hormones. Nerve cells in the front of the hypothalamus make two more hormones that nerve fibres carry to the rear of the pituitary.





Pancreas

The pancreas has two roles. Most of its tissues are gland cells that make digestive enzymes for release along ducts into the small intestine. The endocrine tissues release the hormones insulin and glucagon directly into the bloodstream. These two hormones maintain steady levels of glucose – the sugar removed from food to fuel the body – in the blood.



Pancreatic islets

The tissue inside the pancreas is dotted with more than one million clusters of cells called islets of Langerhans (centre). In the 1890s, scientists discovered the cells released secretions, later called hormones.

Sir Frederick Banting (1891–1941)

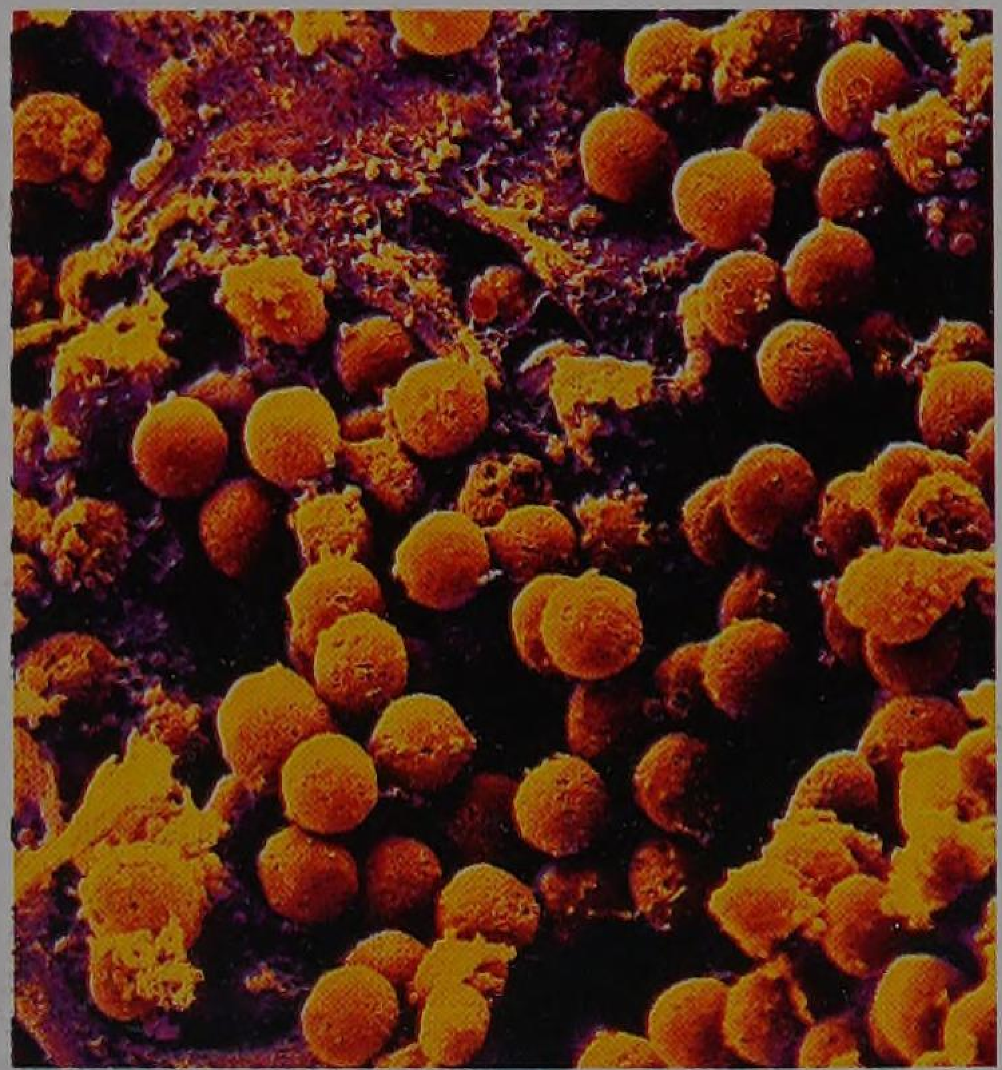
Charles Best (1899–1978)

The insulin story

A lack of the hormone insulin in the body causes a serious condition called diabetes, where blood glucose levels soar. In 1922, Canadian Frederick Banting and American Charles Best successfully extracted insulin so that it could be used to treat and control this disorder.

Pituitary gland

The pea-sized pituitary gland is attached to the base of the brain and has separate front and rear parts, or lobes. Front lobe cells make six hormones that affect metabolism, growth, and reproduction, usually by triggering another gland to release hormones. The rear lobe stores and releases anti-diuretic hormone (ADH), which controls urine's water levels, and oxytocin, which makes the uterus contract during labour.



Thymus gland

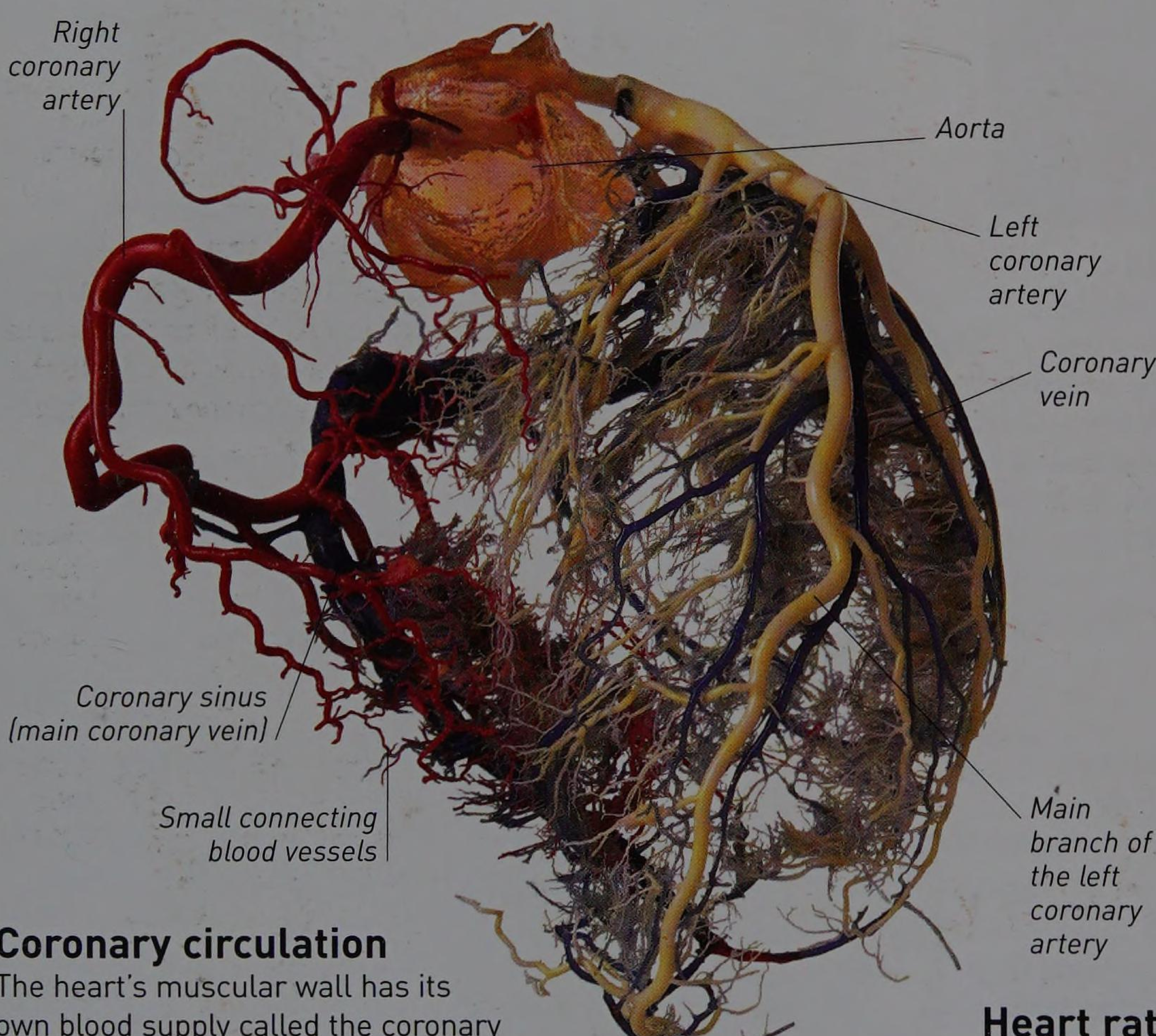
The thymus gland is large in childhood but shrinks in adult life. During a child's early years, it produces two hormones that ensure the normal development of white blood cells called T cells, or T lymphocytes. These identify and destroy disease-causing organisms, such as bacteria. This SEM shows undeveloped T cells (yellow) in the thymus gland.

The heart

Organ storage
In Egyptians mummies, most body organs were removed and stored in jars such as these. The heart was left in place, ready for the afterlife.

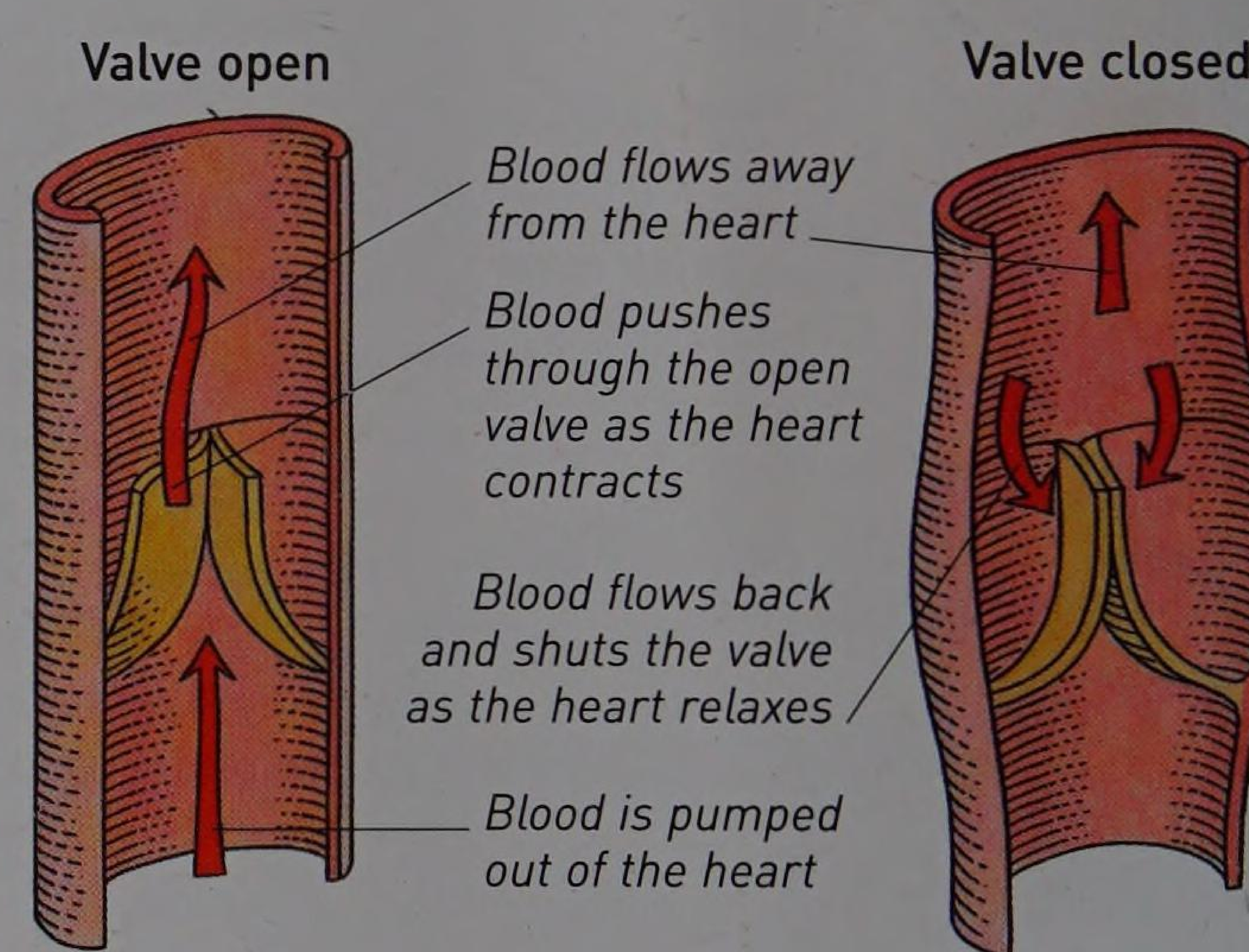
The ancient Egyptians believed the heart housed the soul. For the Greeks it was the seat of love and intelligence. In fact it is an extraordinarily reliable, muscular pump, with a separate right and left side. Each side has two linked chambers – an upper, thin-walled atrium and a larger, thick-walled ventricle below. The right ventricle pumps oxygen-poor blood to the lungs to pick up oxygen and then back to the left atrium. The left ventricle pumps oxygen-rich blood around the body and back to the right atrium. To do this, the heart beats some billion times in an average lifetime.

The right connections
Italian anatomist Andrea Cesalpino (1519–1603) realized how the heart connects to the main blood vessels and the lungs, but not how the circulatory system works (p. 44).



Coronary circulation

The heart's muscular wall has its own blood supply called the coronary circulation, which delivers oxygen to keep the heart beating. Left and right coronary arteries stem from the aorta and branch out to carry oxygen-rich blood to all parts of the heart wall. Oxygen-poor blood is taken by coronary veins to the coronary sinus. This large vein at the back of the heart empties blood into the right atrium, ready to go round the heart again.

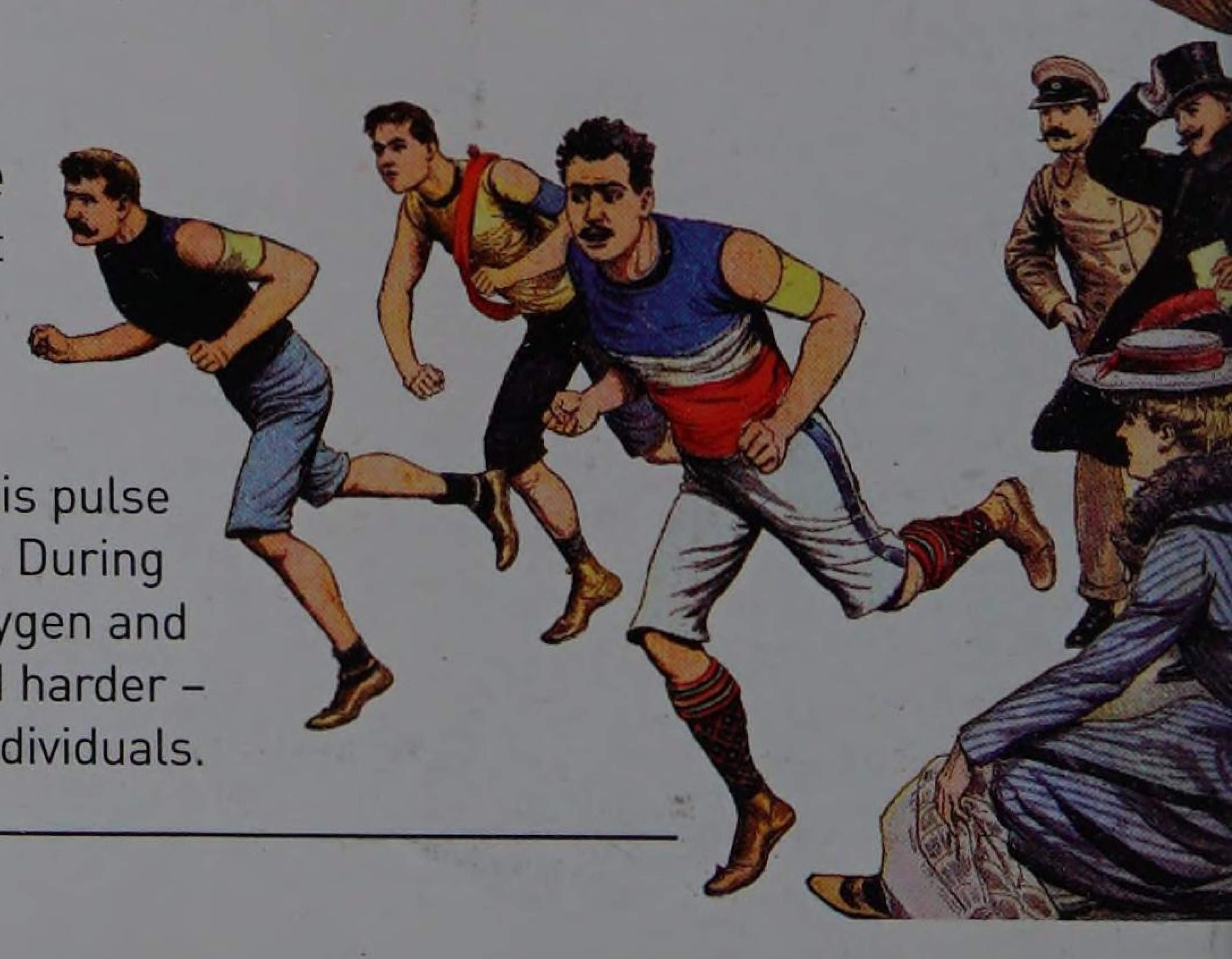


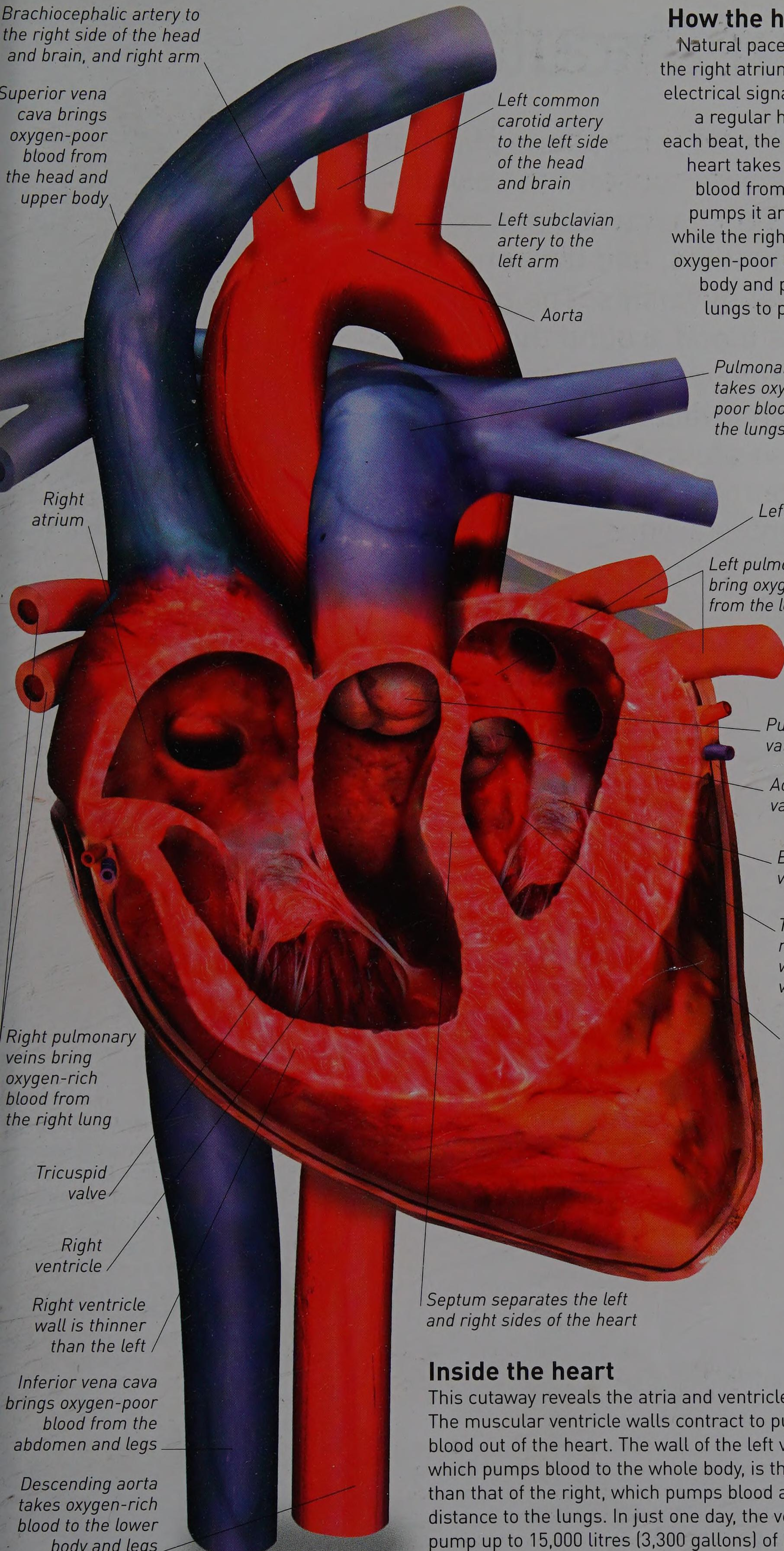
Valves at work

Valves ensure the one-way flow of blood. The aortic and pulmonary valves at the two exits from the heart have pocket-shaped flaps of tissue. When the heart contracts, blood pushes its way out, pressing the flaps open. When the heart relaxes, blood tries to flow back, pressing the flaps shut.

Heart rate

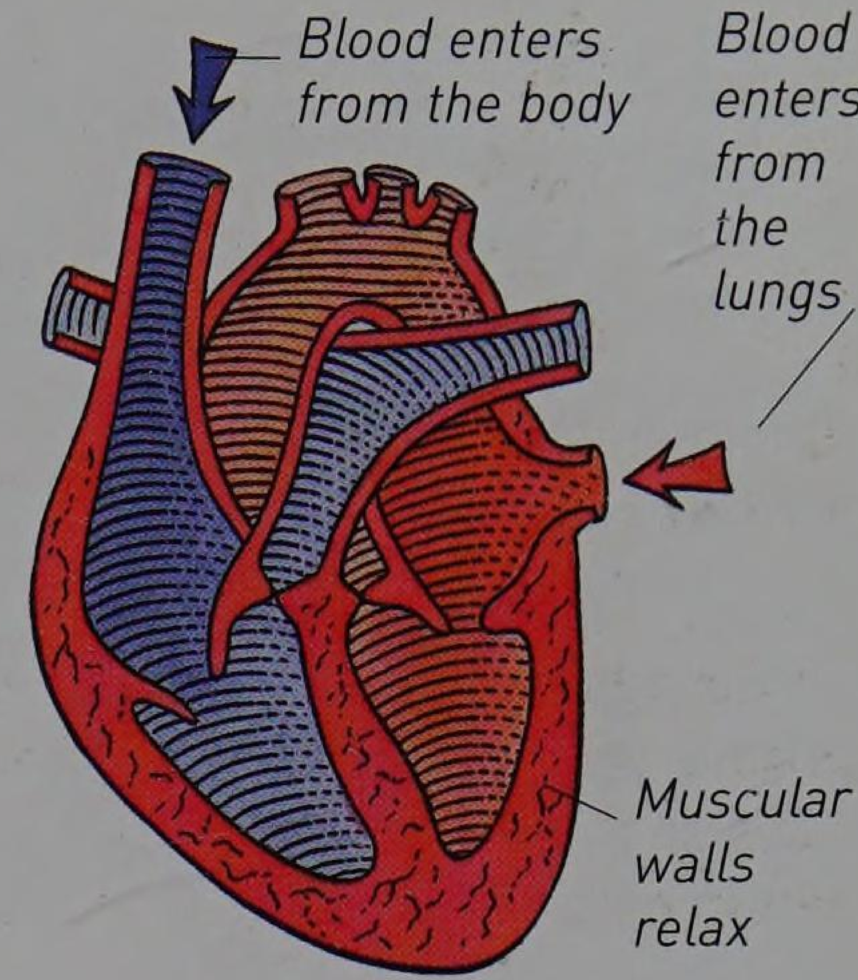
The average adult heart beats 60–80 times, pumping up to 6 litres (11 pints) of blood, every minute. Each beat creates a pressure surge through the body's arteries. This pulse can be felt in the artery in the wrist. During activity, the muscles need more oxygen and nutrients, so the heart beats faster and harder – up to 150 times a minute in the fittest individuals.





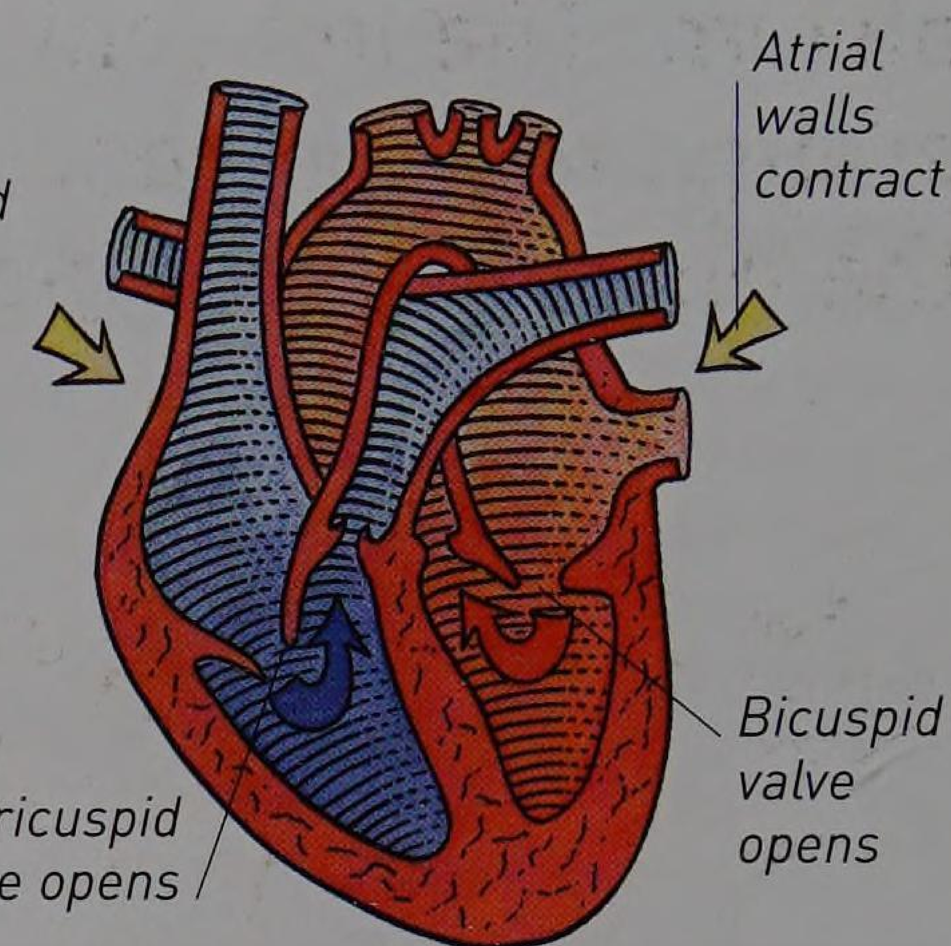
How the heart beats

Natural pacemaker cells in the right atrium wall produce electrical signals to maintain a regular heartbeat. With each beat, the left side of the heart takes in oxygen-rich blood from the lungs and pumps it around the body, while the right side receives oxygen-poor blood from the body and pumps it to the lungs to pick up oxygen.



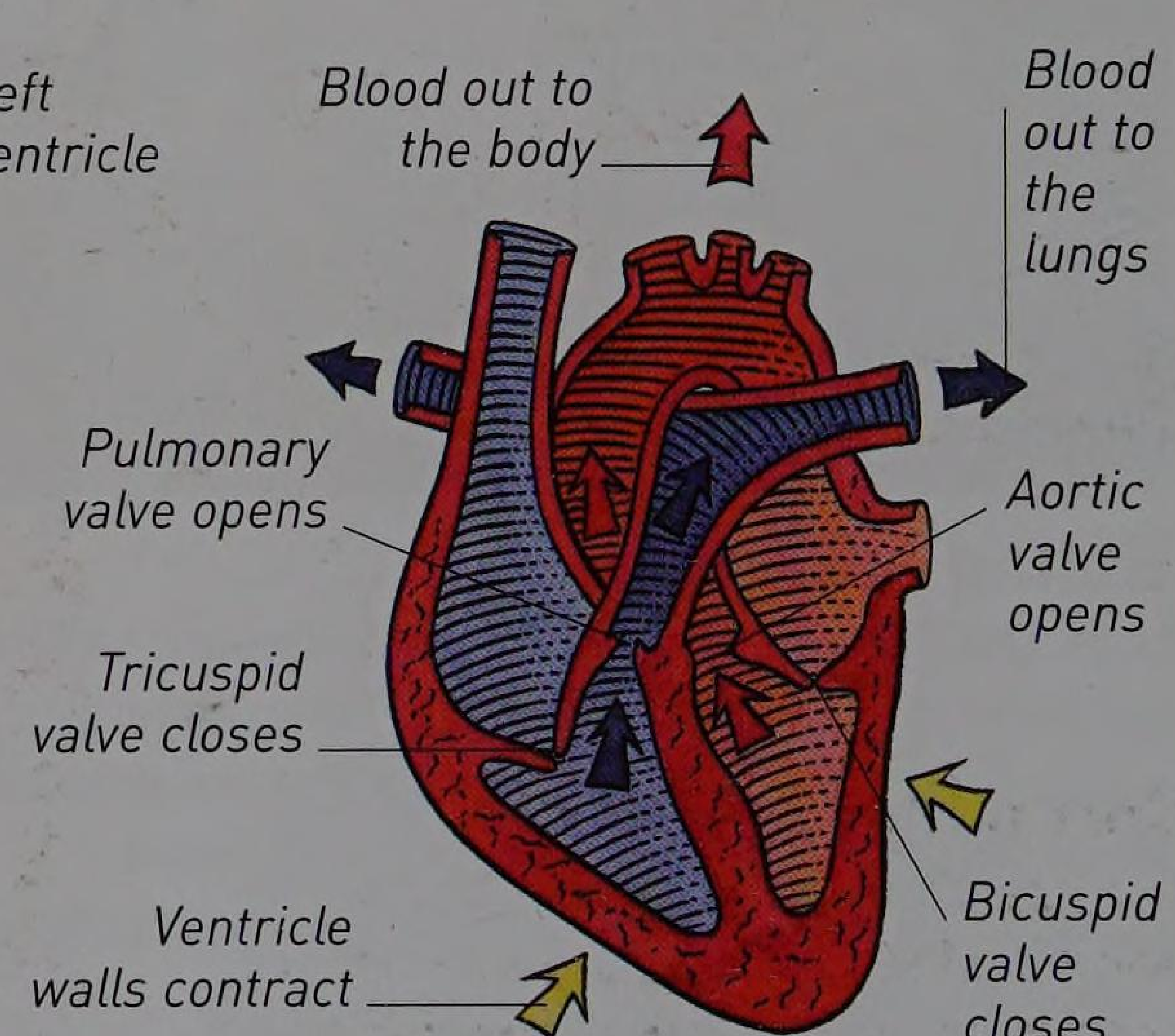
1 Relax and refill

When the cardiac muscle relaxes, blood flows in under low pressure to the right atrium from the body, and to the left atrium from the lungs.



2 Atria contract

An electrical signal from the pacemaker cells causes the atria to contract. This pumps blood into the ventricles, through their tricuspid and bicuspid valves.



3 Ventricles contract

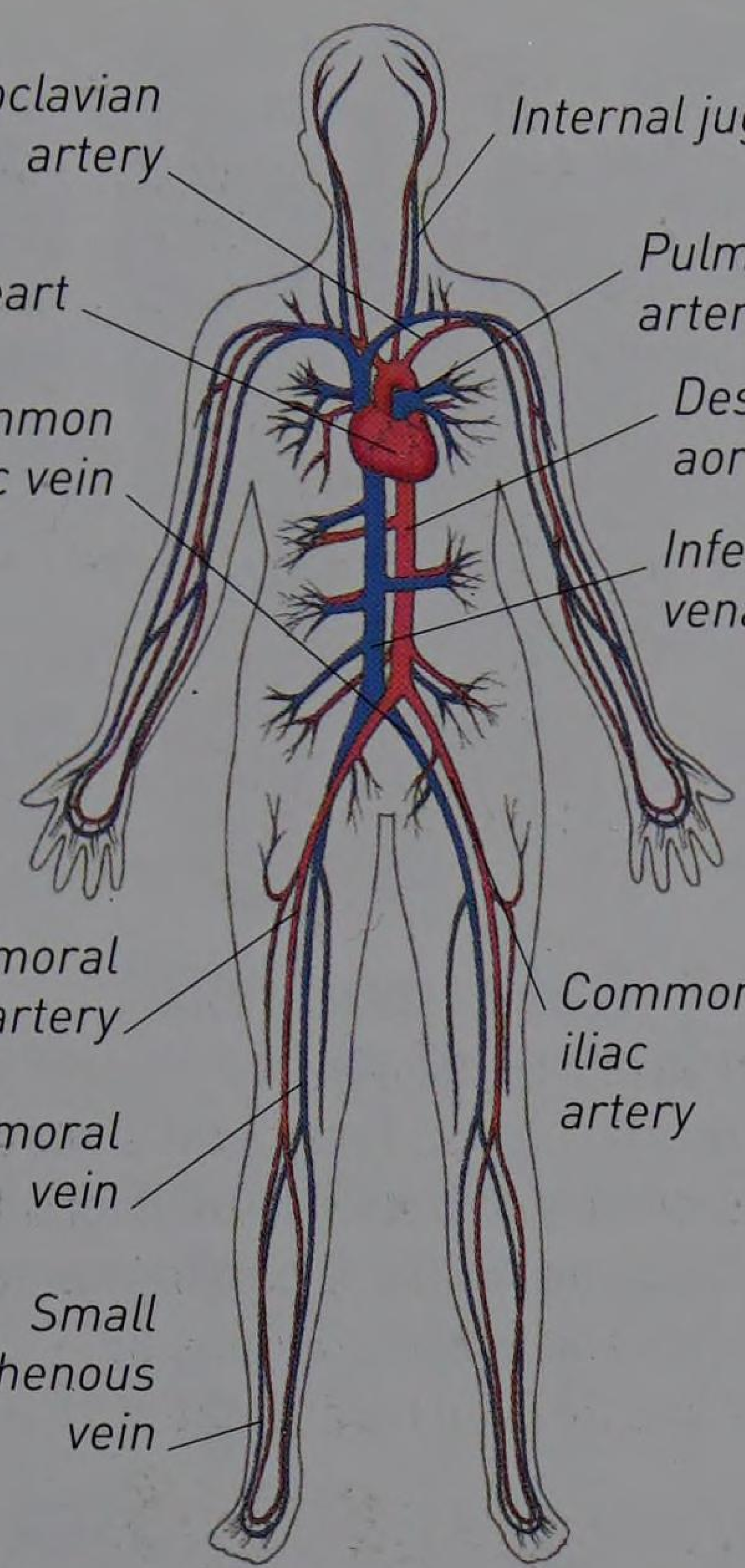
The electrical signal passes through the ventricle walls, so they contract. Blood is forced into the aorta and pulmonary artery, and the ventricles valves snap shut – producing the heartbeat you hear.

Inside the heart

This cutaway reveals the atria and ventricles. The muscular ventricle walls contract to pump blood out of the heart. The wall of the left ventricle, which pumps blood to the whole body, is thicker than that of the right, which pumps blood a shorter distance to the lungs. In just one day, the ventricles pump up to 15,000 litres (3,300 gallons) of blood.

In circulation

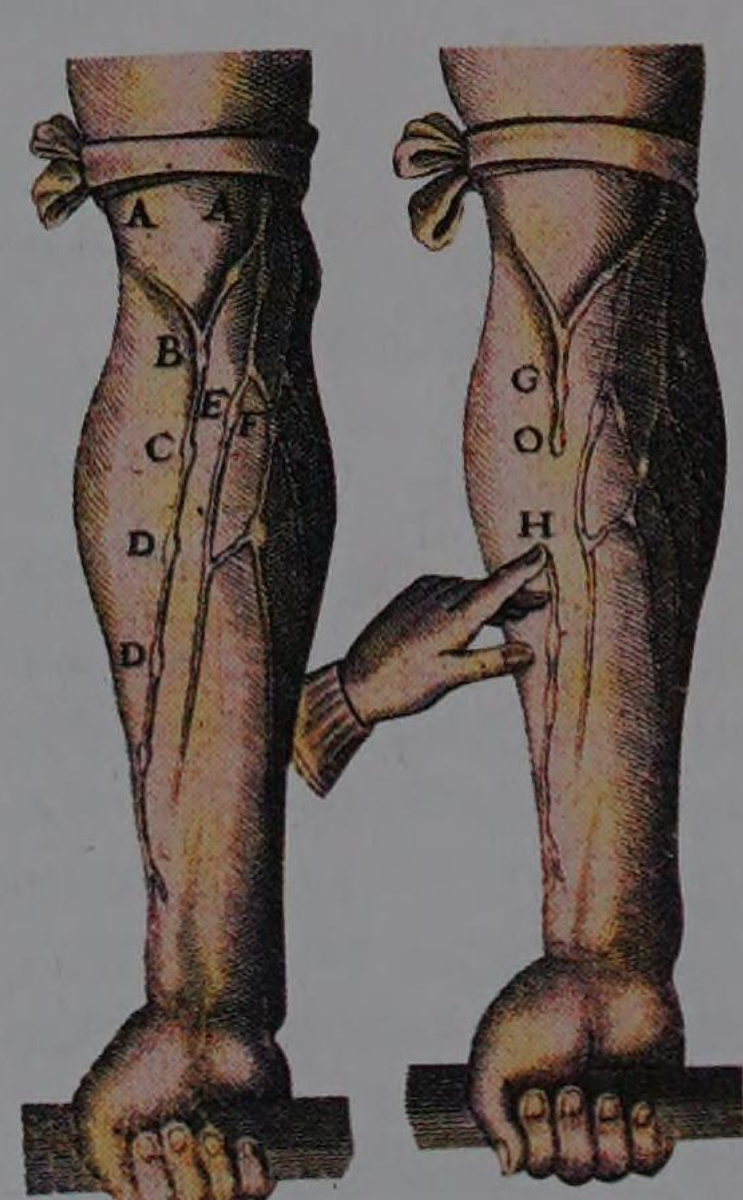
The body's trillions of cells need a constant supply of oxygen, nutrients, and other essentials, and the constant removal of wastes. The heart pumps blood around the body, delivering essentials to cells through a vast network of blood vessels. A second transport system, called the lymphatic system, drains excess fluid from the tissues. The two systems also play key parts in fighting disease.



Circulatory system
Arteries carry oxygen-rich blood from the heart to body tissues, and veins return oxygen-poor blood from the tissues to the heart. Capillaries, too small to be seen here, carry blood through the tissues and connect arteries to veins.

William Harvey, with King Charles I (seated)

Round and round
Until the 17th century, blood was thought to flow backwards and forwards inside arteries and veins. Experiments by English physician William Harvey (1578–1657) showed how the heart pumped blood around the body in one direction.



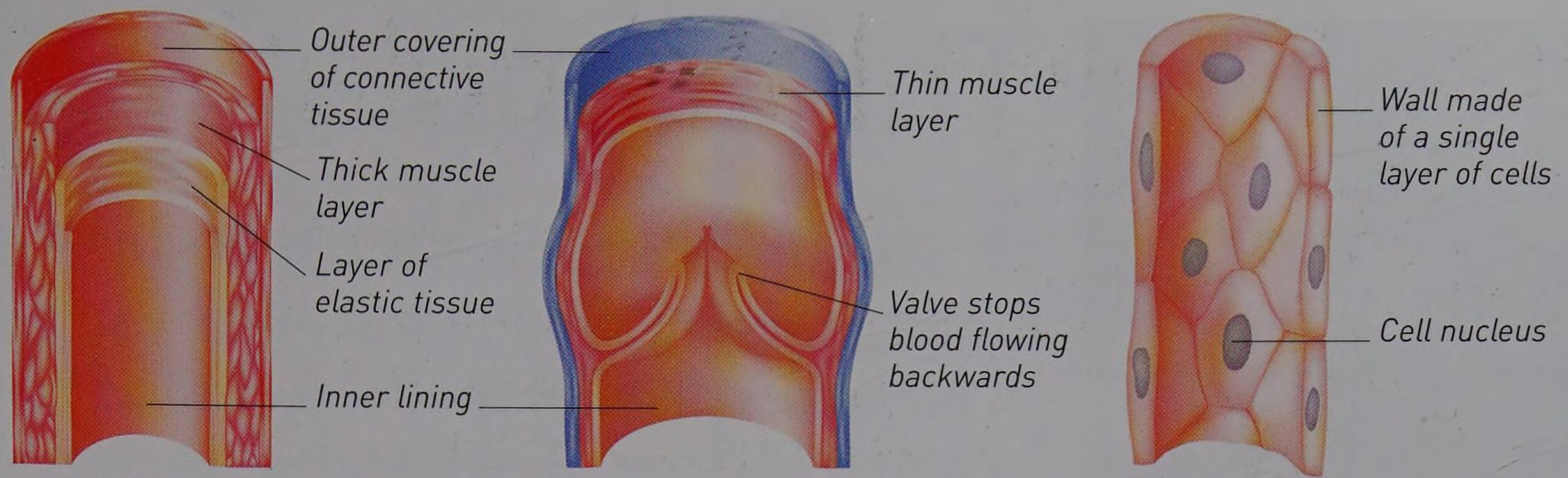
Vein valves
Harvey based his theory of blood circulation on careful study, not tradition. His approach marked the beginning of scientific medicine. Harvey's illustrations show how the blood in veins always flows towards the heart. Valves, here marked by letters, prevent it from seeping backwards.

Blood vessels of the leg
The external iliac artery carries oxygen-rich blood from the heart to the leg. Here it divides into branches that then subdivide to form the microscopic capillaries that deliver oxygen and nutrients to cells, and remove their waste products. The capillaries then rejoin, forming larger vessels that connect into the network of major veins that carry oxygen-poor blood from the leg back towards the heart.

Vessel investigator
Swiss-born anatomist Albrecht von Haller (1708–77) investigated how muscle in the wall of smaller arteries could contract or relax to vary the amount of blood flowing to a particular body part.

Blood vessels

With every heartbeat, an artery's walls expand and shrink as blood from the heart surges through it at high pressure. Veins carry blood returning from capillaries at low pressure, so their wall layers are thinner and less muscular. Just one cell thick, capillary walls let food and oxygen pass from blood into the surrounding tissues.



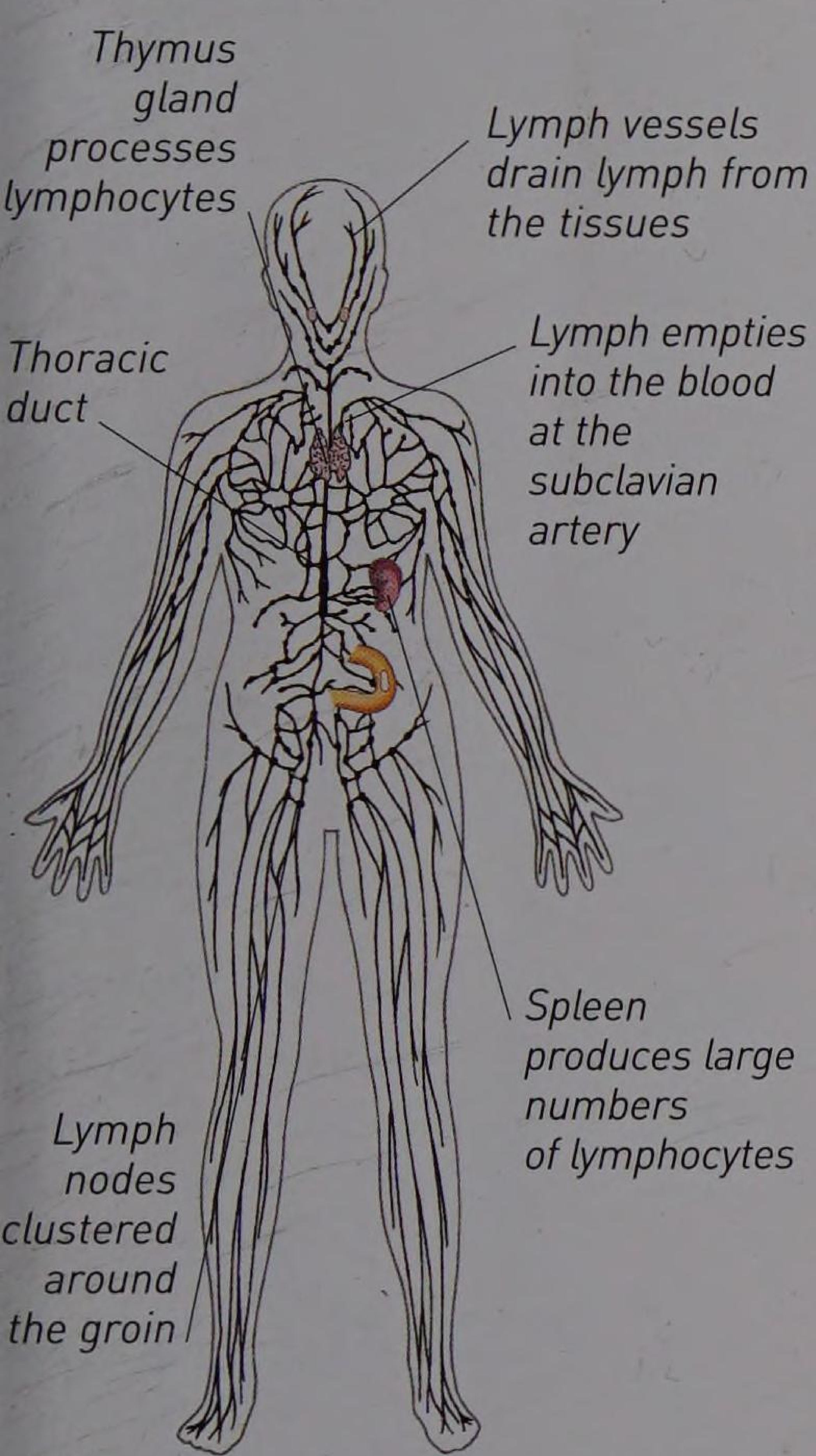
Artery

Vein

Capillary

Fighting infection

Every day, the body is exposed to pathogens – microscopic organisms, such as bacteria and viruses, that cause disease if they invade the body's tissues and bloodstream. White blood cells in the circulatory and lymphatic systems form the body's immune, or defence, system. Some patrol the body and search for invaders to destroy. Others attack specific pathogens and retain a memory of them, in case the same pathogens return to infect the body.

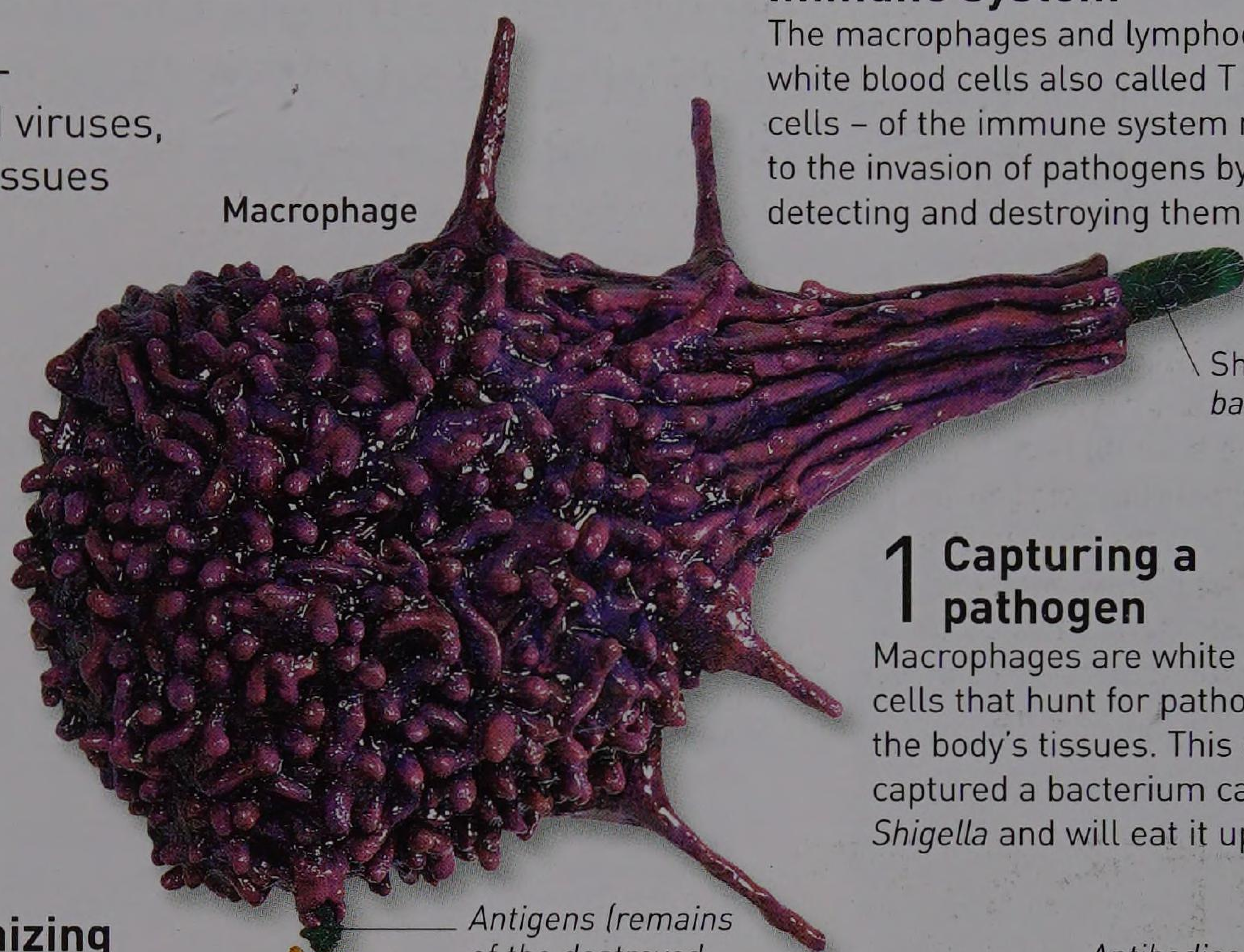


Lymphatic system

This network of vessels drains excess fluid from the body's tissues and returns it to the bloodstream. The lymphatic system has no pump, instead the contractions of skeletal muscles push the fluid, called lymph, along the lymph vessels. As it flows, lymph passes through small swellings called lymph nodes.

Immune system

The macrophages and lymphocytes – white blood cells also called T and B cells – of the immune system respond to the invasion of pathogens by detecting and destroying them.



Macrophage

1 Capturing a pathogen

Macrophages are white blood cells that hunt for pathogens in the body's tissues. This one has captured a bacterium called *Shigella* and will eat it up.

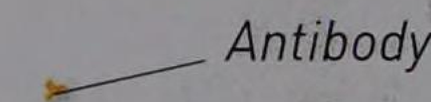
2 Recognizing antigens

The macrophage displays antigens, or the remains of the bacterium, on its surface, to activate a helper T cell.

Helper T cell

5 Disabling the pathogen

Antibodies bind to the antigens on the *Shigella* bacterium's surface. This tags it for macrophages or other white blood cells to destroy.



B cell

3 Spurred into action

The helper T cell releases substances that switch on a B cell that targets *Shigella*. The B cell multiplies to produce plasma cells.

4 Making antibodies

Plasma cells release billions of antibody molecules into the blood and lymph. The antibodies track down any *Shigella* bacteria present in the body.

Plasma cell

The blood

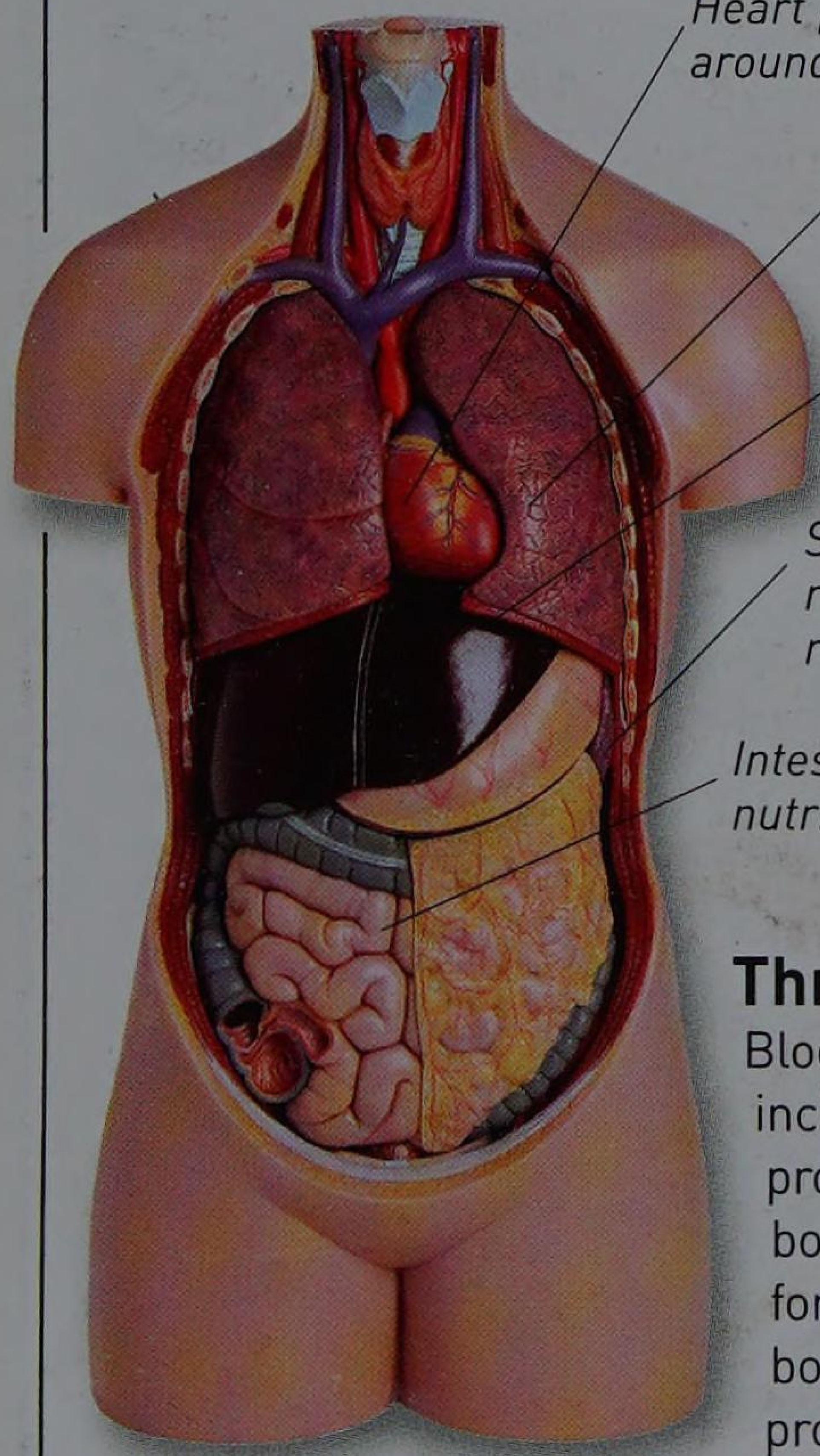
Feeding on blood
Leeches and vampire bats feed on the blood of other animals. This scene from the 1978 film *Nosferatu* shows a mythical human vampire feeding on blood to gain immortality.

An average adult has 5 litres (9 pints) of blood coursing around the body. Each drop of blood consists of millions of cells floating in liquid plasma. Red blood cells deliver essential oxygen to the body's tissues, while defence cells fight off infections. Blood also distributes heat to keep the body at a steady 37°C (98.6°F) – the ideal temperature for cells to function.

Blood transfusions
Before the discovery of blood groups, the transfusion (transfer) of blood from a donor – usually a healthy person, but here a dog – to a sick patient, often failed, killing the patient.

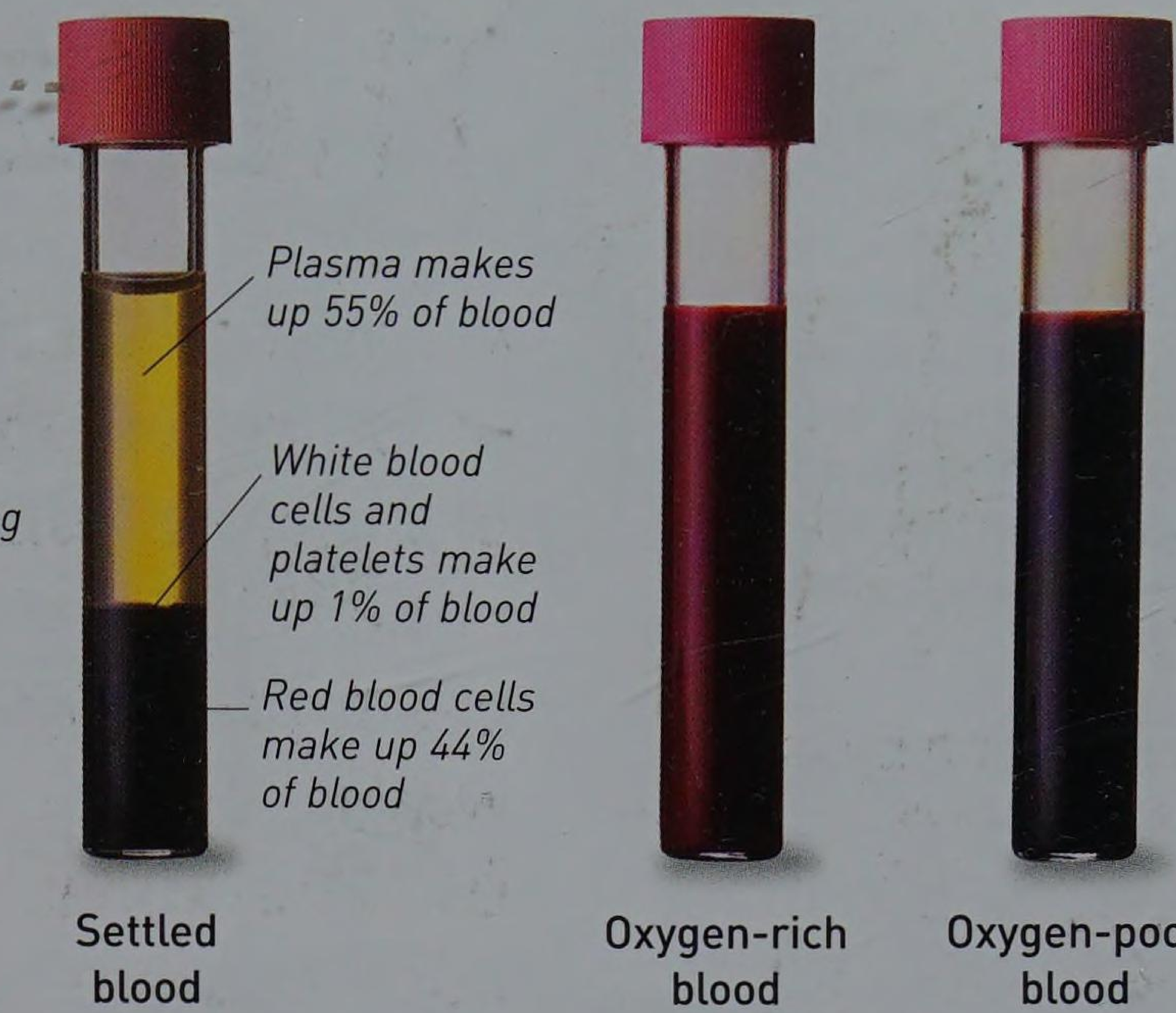
Red and white blood cells

Each type of blood cell has a vital role to play in the body. Red blood cells, by far the most numerous, transport oxygen to body cells. White blood cells, including neutrophils and lymphocytes help to defend the body against pathogens, or disease-causing germs. Neutrophils track down pathogens such as disease-causing bacteria, and then eat them. Lymphocytes are part of the immune system that targets and destroys specific germs. Platelets help to seal wounds by forming blood clots.



Three main roles

Blood transports a range of substances, including oxygen, nutrients, and waste products from cells. It also protects the body by carrying white blood cells and forming blood clots. And it controls body temperature by distributing heat produced by organs around the body.

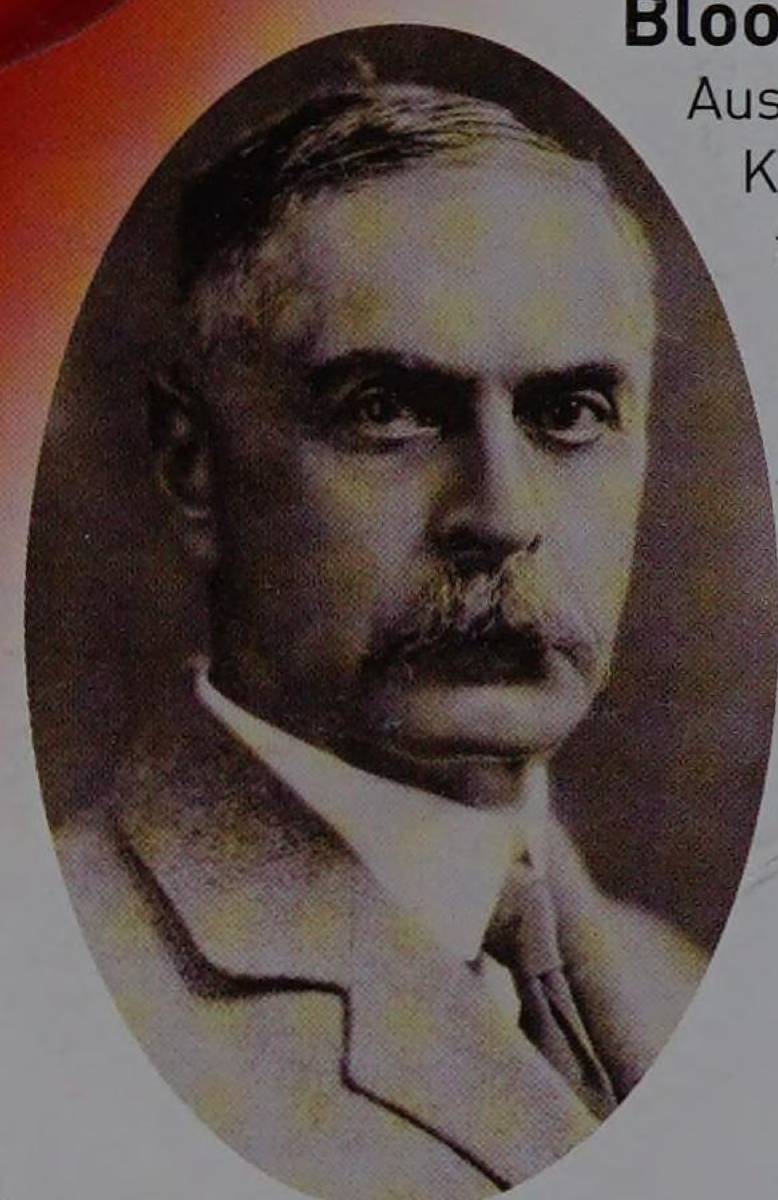


Blood components

If allowed to settle, blood separates into three parts. The red and white blood cells float in a yellow liquid called plasma. This is mainly water containing over 100 substances including oxygen, nutrients, blood proteins, hormones, and wastes.

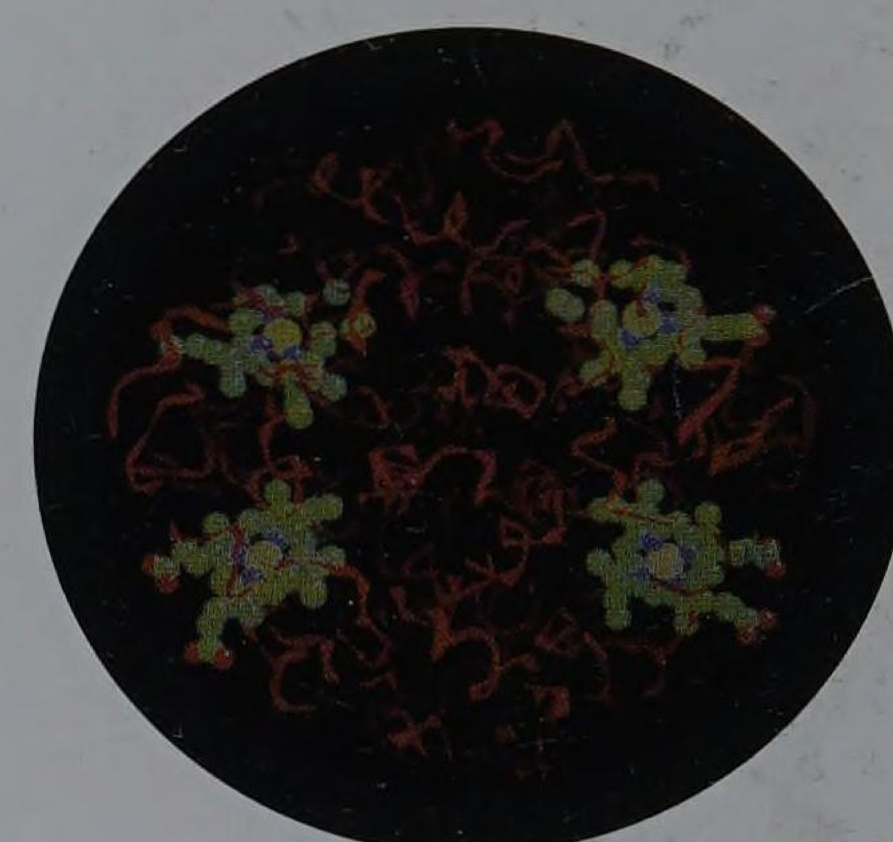
Changing colour

Blood takes its colour from the red blood cells. When they pick up oxygen in the lungs, blood turns bright red. Once they unload oxygen in the tissues, blood turns a darker shade of red.



Blood groups

Austrian-American scientist Karl Landsteiner (1868–1943) found that people belonged to one of four blood groups: A, B, AB, or O. Doctors can now match up blood types to avoid a body rejecting a blood transfusion from the wrong blood group.

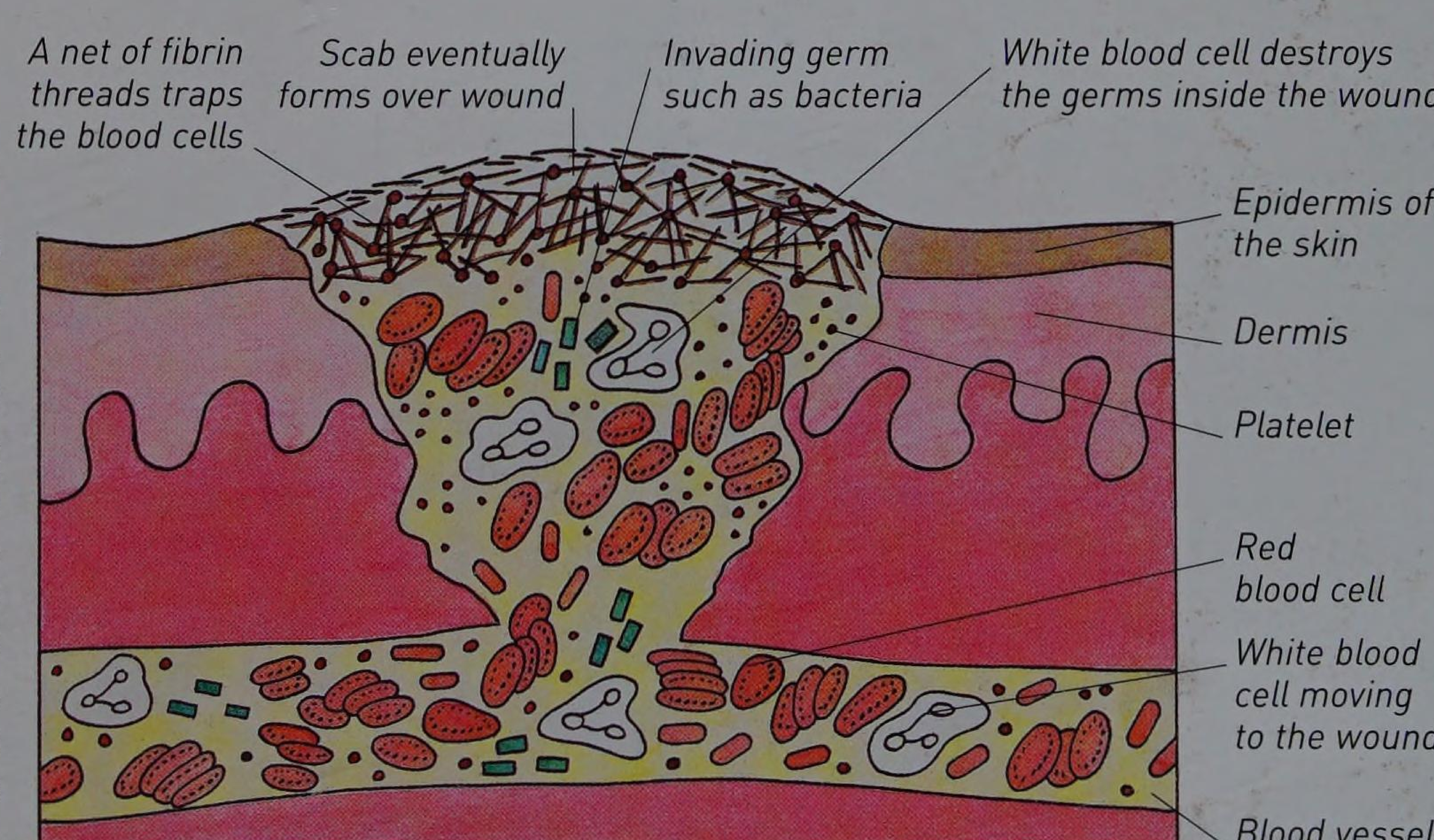


Oxygen carrier

The protein haemoglobin carries oxygen and gives red blood cells their colour. This computer-generated image shows the structure of its molecules. Each molecule contains four iron atoms (yellow). The iron atoms bind oxygen in the lungs, where oxygen is abundant, and release it wherever oxygen is in short supply in the body.

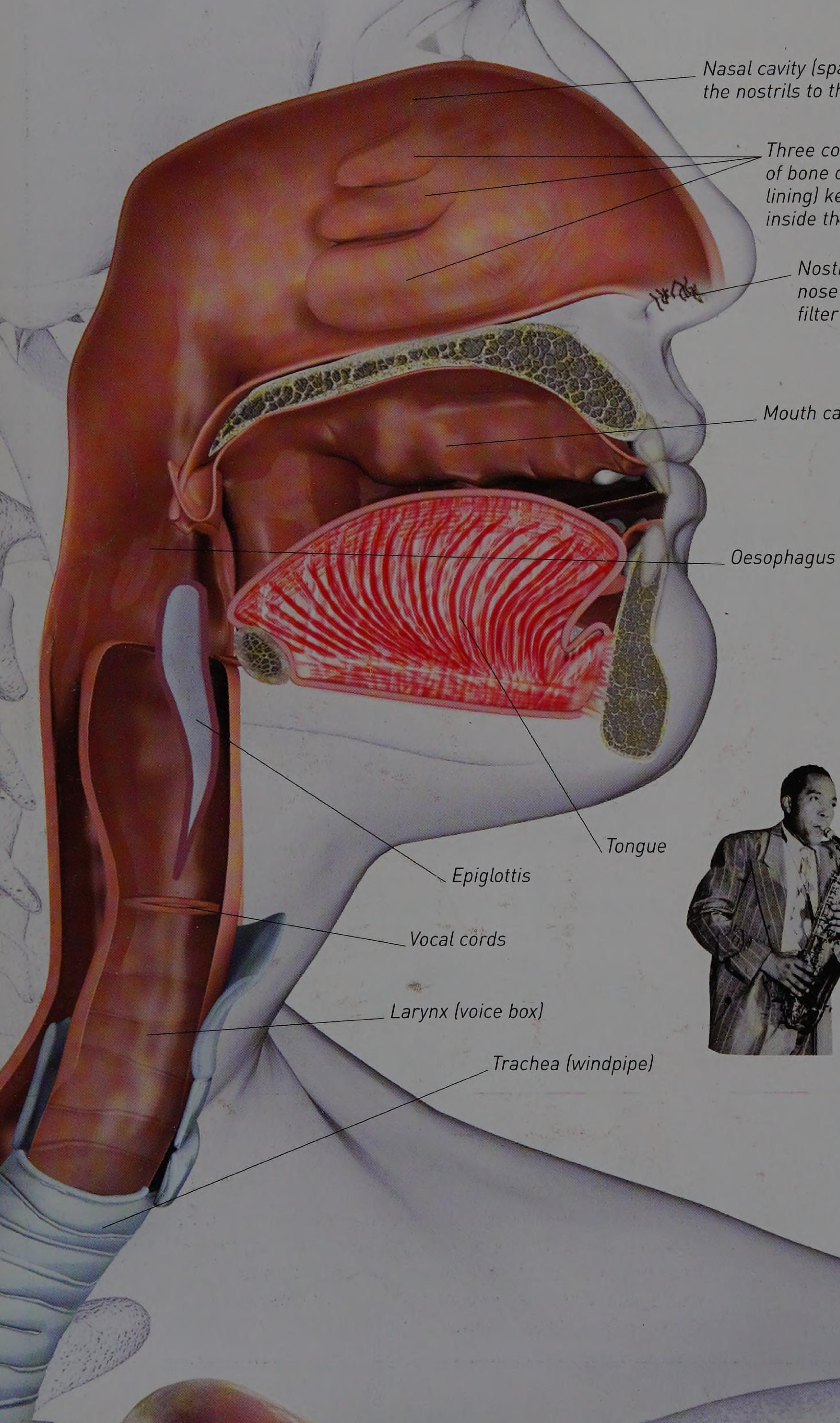
Forming blood clots

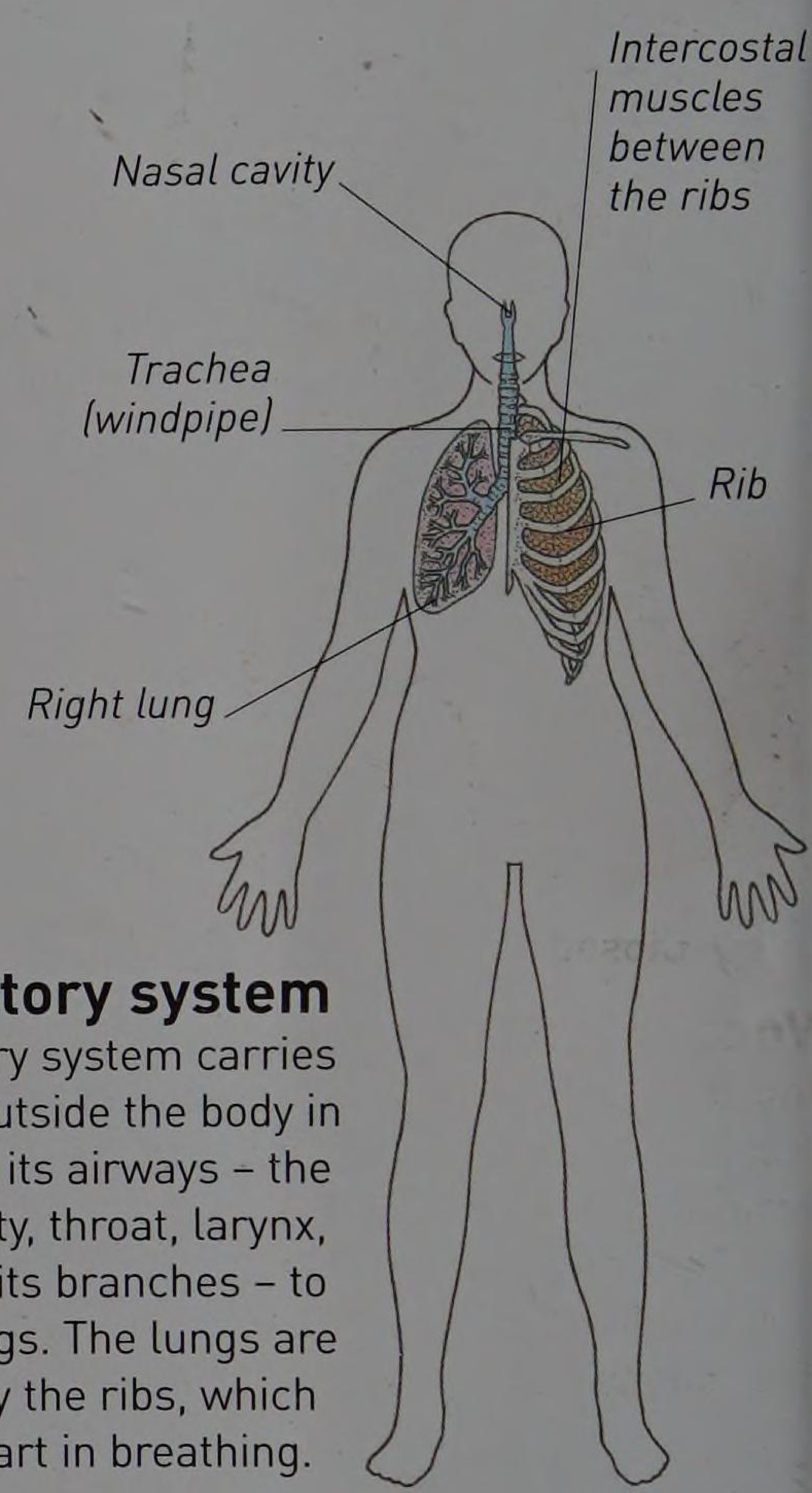
This cross-section of a skin wound shows how blood reacts. Platelets stick together to briefly form a plug. They also release chemicals that convert a blood protein into threads of fibrin, which trap blood cells to form a jelly-like clot. White blood cells destroy any invading bacteria. The clot dries out to form a protective scab over the tissues while they repair themselves.



Breathing to live

The body can survive without food or water for some time, but soon dies if breathing stops. Breathing brings fresh air containing oxygen into the lungs, and then expels stale air containing waste carbon dioxide.





Respiratory system

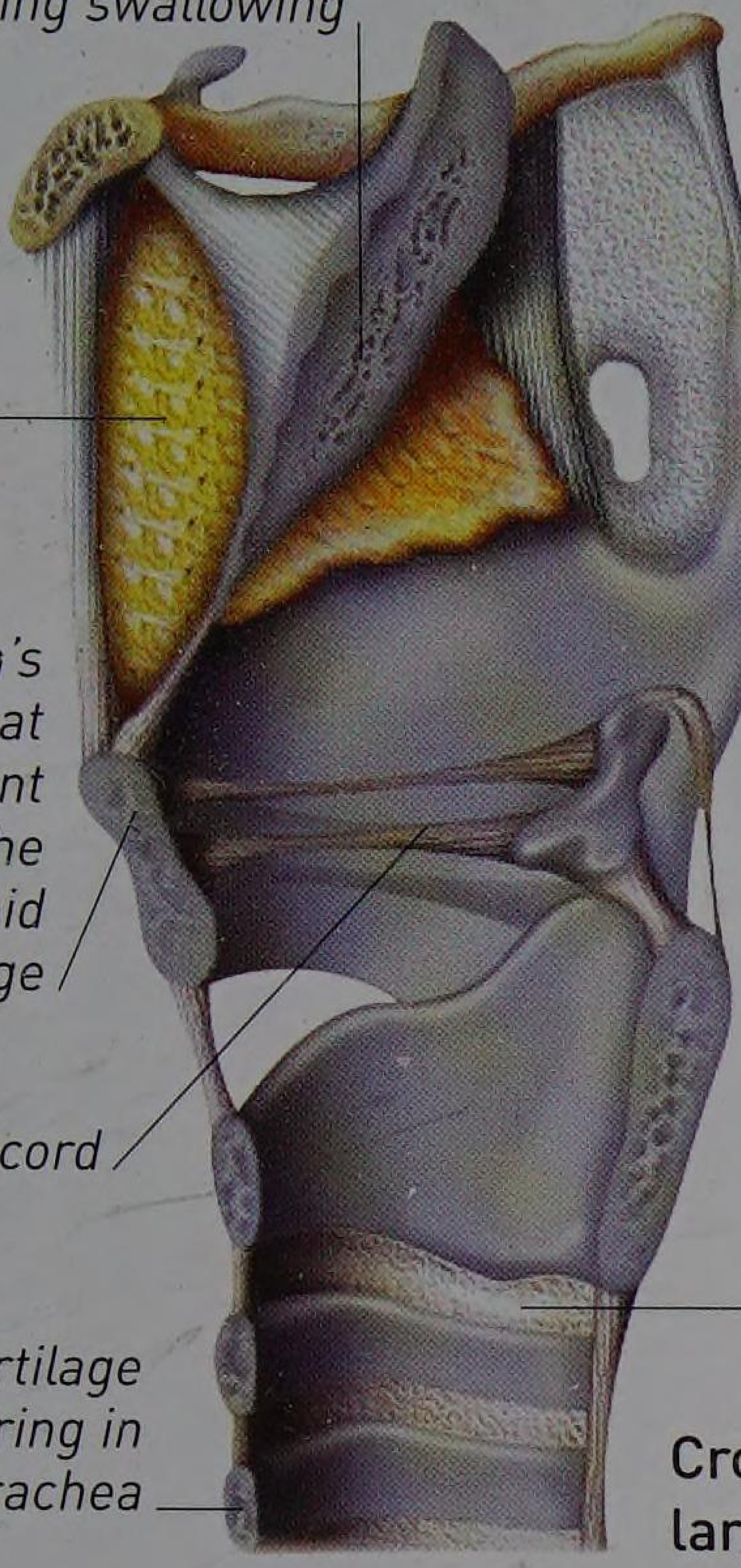
The respiratory system carries air from outside the body in through its airways – the nasal cavity, throat, larynx, trachea, and its branches – to a pair of lungs. The lungs are protected by the ribs, which also play a part in breathing.

Controlled breathing

Musicians like Charlie Parker (left) and Miles Davis need great breath control to play the saxophone, trumpet, and other wind instruments. Precisely timed contractions of the diaphragm and rib muscles push bursts of air out of the mouth and into the instrument. Blowing with varying force and duration produces different notes.

Upper airways

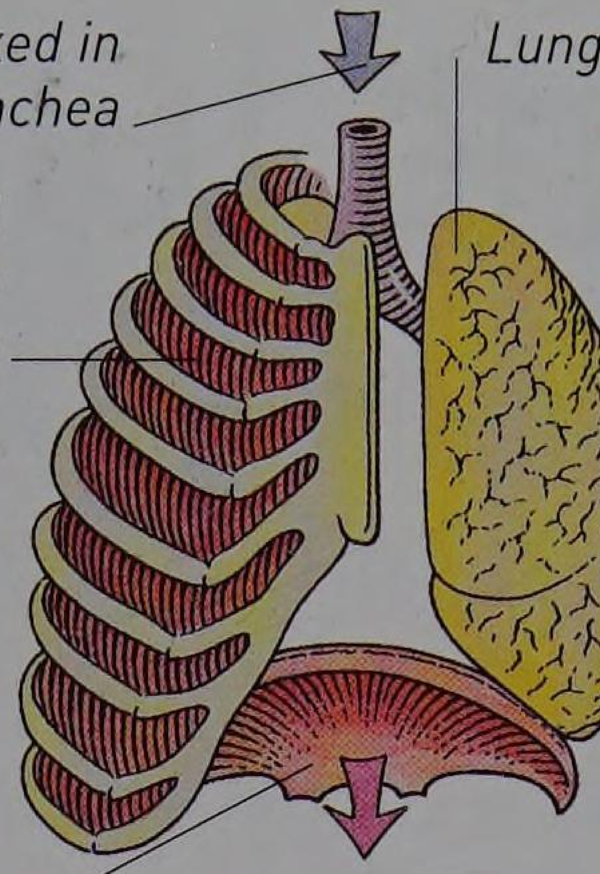
The lungs' delicate tissues are easily damaged by dirt particles, which must be removed in the upper airways after inhalation (breathing in). Nostril hairs filter out larger dirt particles. Sticky mucus covering the nasal lining traps dust and bacteria. The filtered air then passes into the larynx and on to the lungs.



Cross-section of the larynx from the side

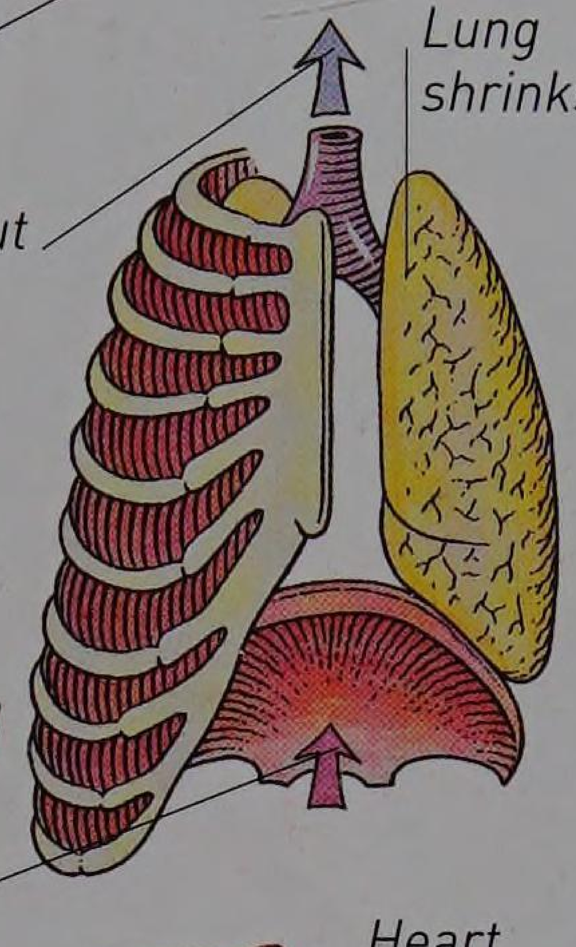
Larynx

During breathing, air passes from the throat, through the larynx, to the trachea (windpipe). The larynx, also called the voice box, is made of nine pieces of cartilage. During swallowing, the entrance to the larynx is covered by a flap of cartilage called the epiglottis, to prevent food from entering the trachea. The vocal cords are two membrane-covered ligaments that produce sound (see below).



Inhalation

The lungs cannot move by themselves. For inhalation (breathing in), the diaphragm and intercostal muscles contract to expand the space inside the chest. As the lungs swell to fill the expanded chest, air is sucked in.



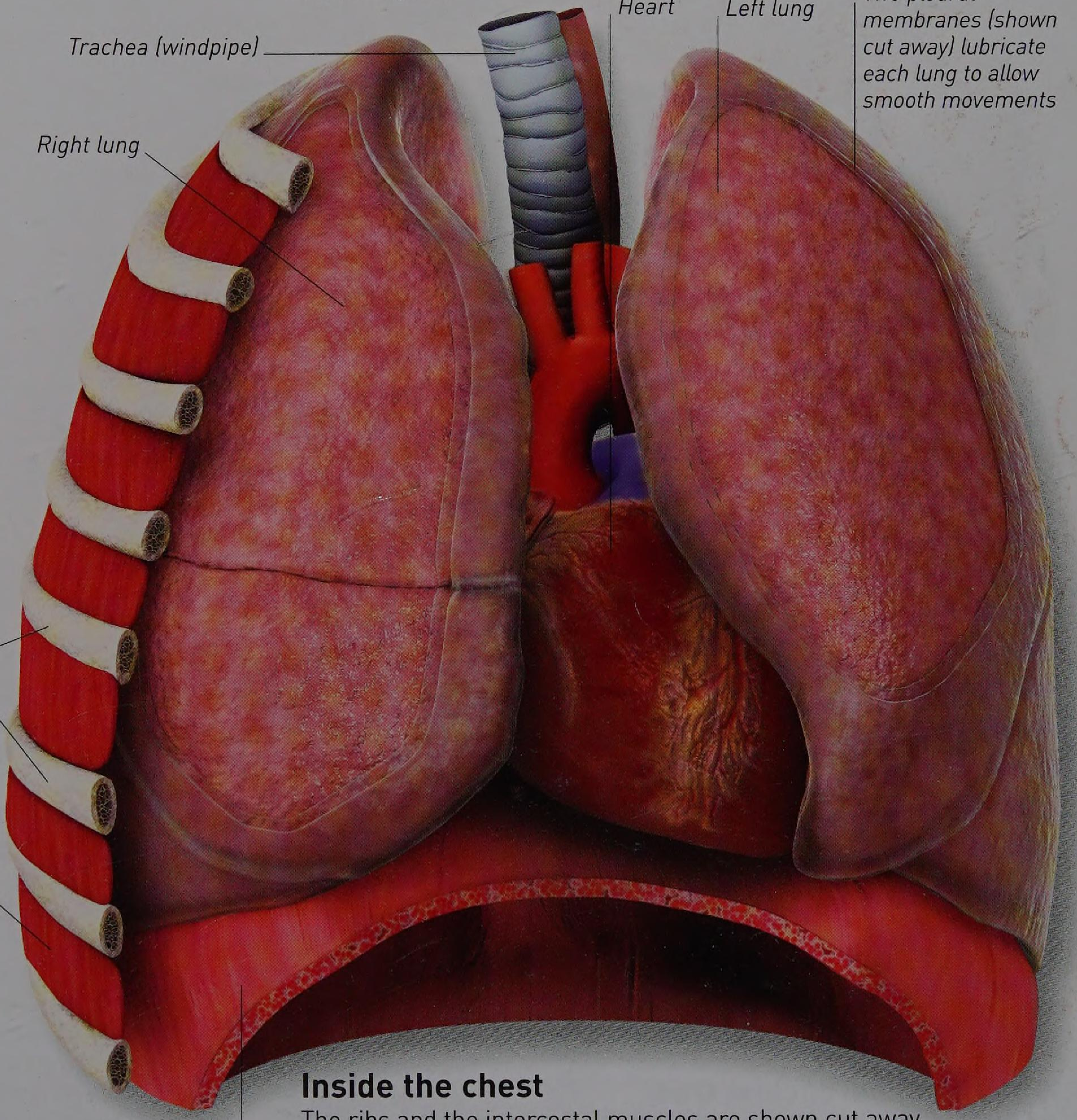
Exhalation

For exhalation (breathing out), the diaphragm and intercostal muscles relax. The rib cage falls and the diaphragm is pushed up by the organs below it. This squeezes the lungs, and air is forced back outside.

Closed **Open**

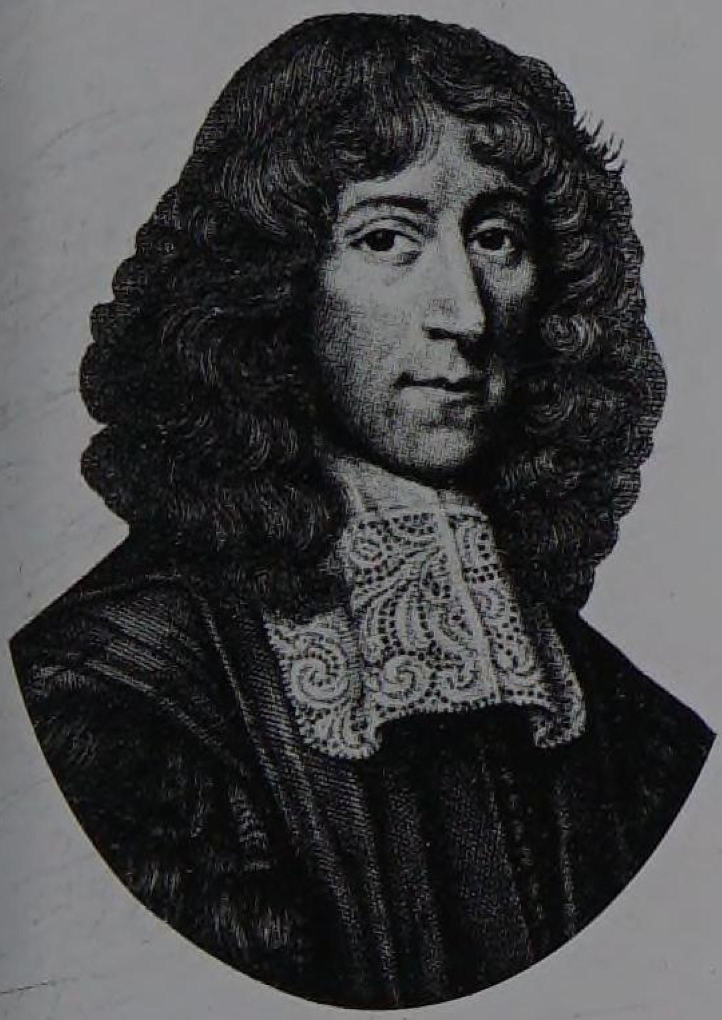
Vocal cords

Inside the throat, when the vocal cords are relaxed, they open to let air in and out for breathing. To make sounds, they are pulled taut as controlled bursts of air are pushed out, making the closed vocal cords vibrate. The tongue and lips turn sounds into speech.



Inside the chest

The ribs and the intercostal muscles are shown cut away to reveal the lungs and diaphragm. When resting, the body breathes at a rate of around 15 times a minute. During exercise, the need for oxygen increases, and so the rate rises up to 50 times a minute.

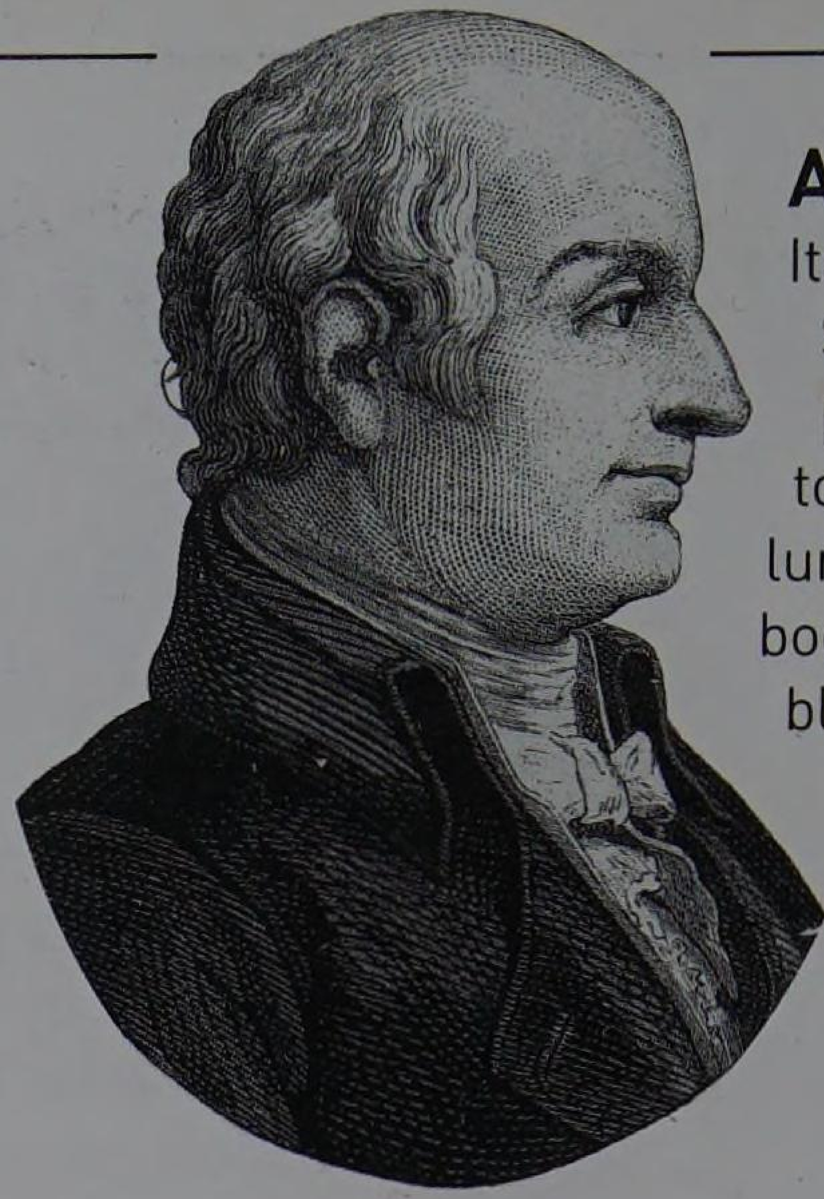


Breathing and burning

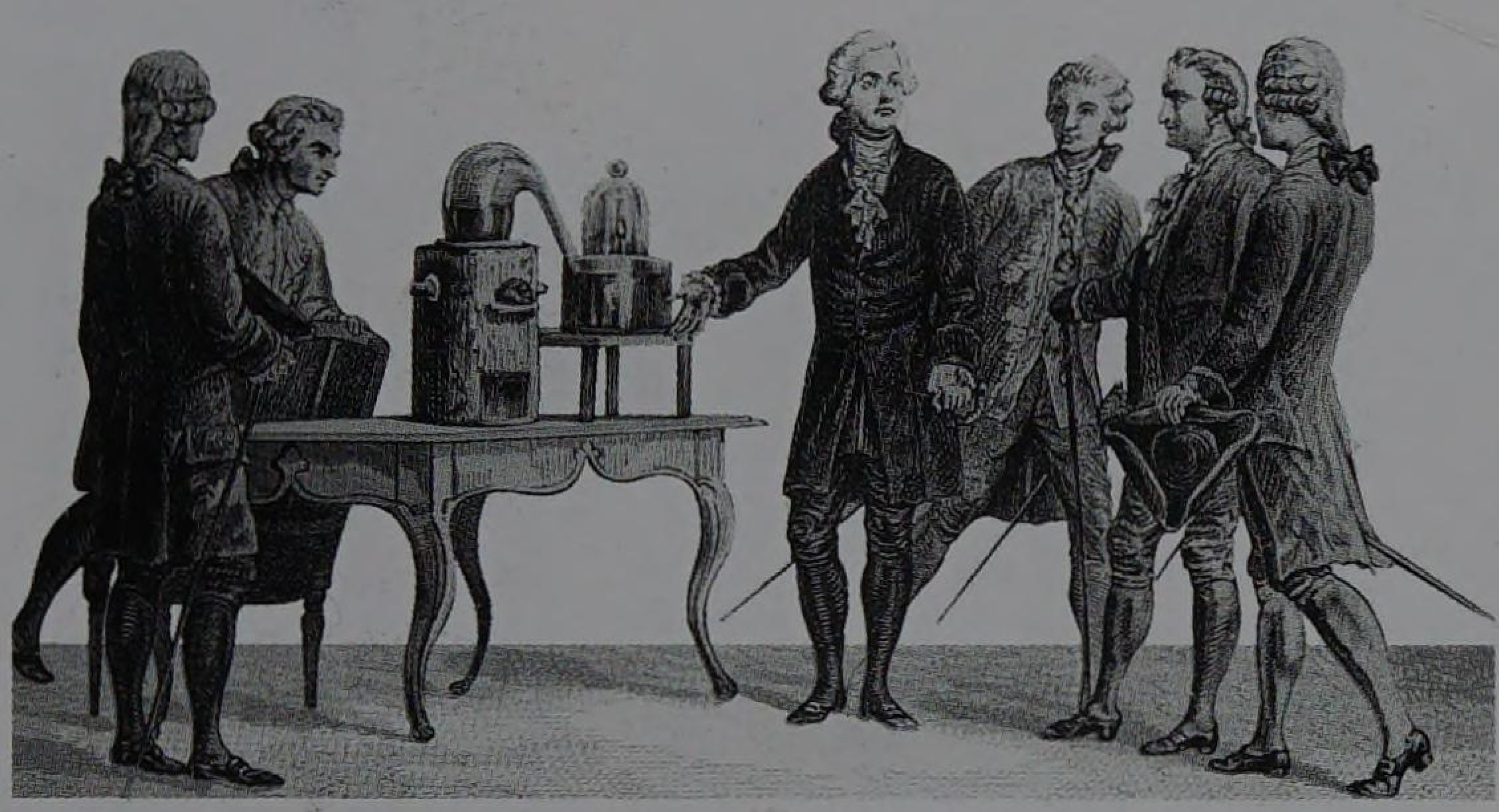
English physician John Mayow (1640–79) showed that if a burning candle and a small animal were put in a sealed jar, the candle went out and the animal died, as part of the air was used up. He realized the same part of air (later named oxygen) was used in the processes of breathing and burning.

Inside the lungs

The lungs are filled with millions of microscopic air sacs called alveoli, each wrapped in a mesh of tiny blood vessels. Alveoli take oxygen from the air we breathe in and pass it into the bloodstream, which delivers oxygen to every body cell to release energy from food in a chemical process known as cell respiration. In exchange, the waste product, carbon dioxide, travels in the bloodstream to the alveoli, where it is expelled.

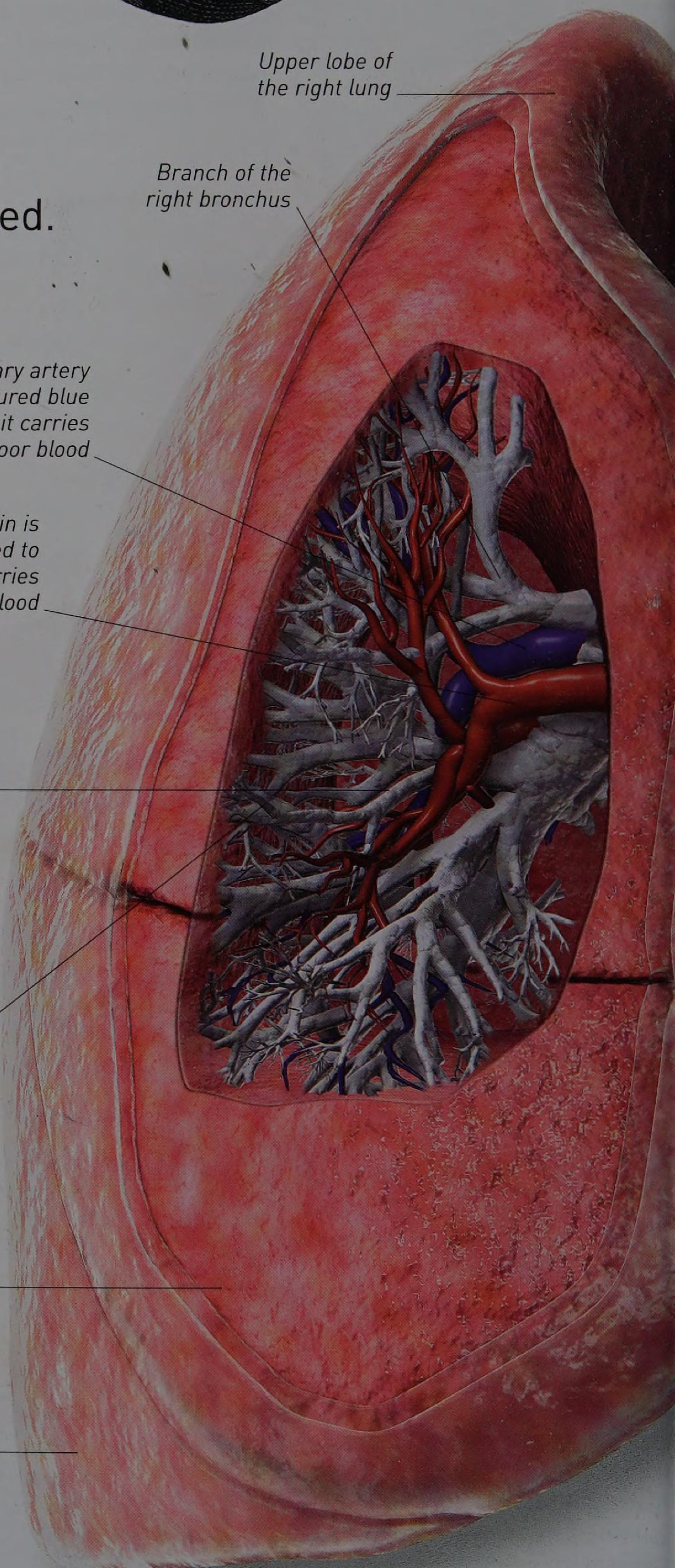


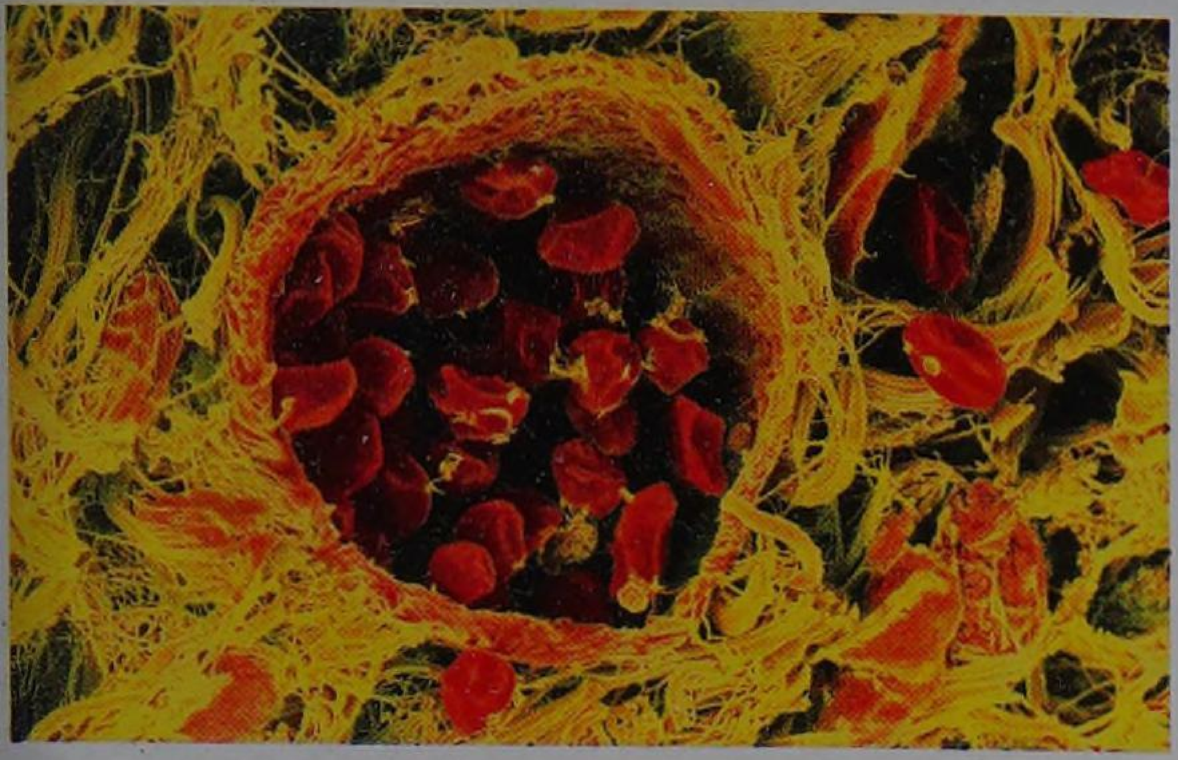
All-over respiration
Italian scientist Lazzaro Spallanzani (1729–99) proposed that respiration took place not just in the lungs, but in every cell of the body. He also discovered that blood delivered oxygen to body tissues and carried away carbon dioxide.



Oxygen gets its name
French chemist Antoine Lavoisier (1743–94) showed that a candle burned using part of the air (a gas he called oxygen) and produced a waste gas (now called carbon dioxide). He suggested animals live by burning food inside the lungs using the oxygen in air – a process he called respiration.

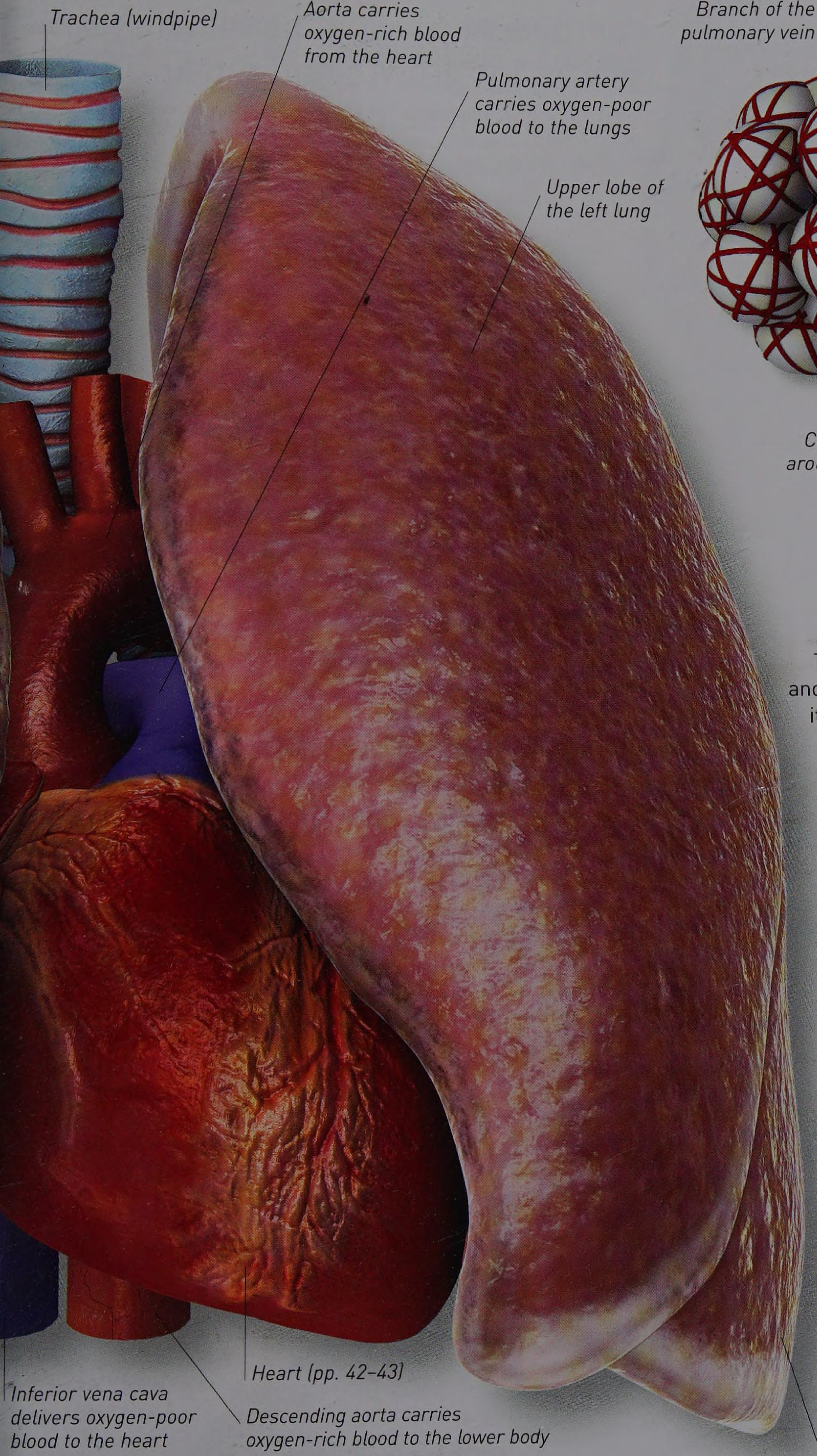
X-ray of the bronchial tree
A branching system of tubes carries air all through the lungs. The trachea divides into two bronchi, one to each lung. Each bronchus splits into many smaller bronchi, then bronchioles, and finally terminal bronchioles, narrower than a hair.





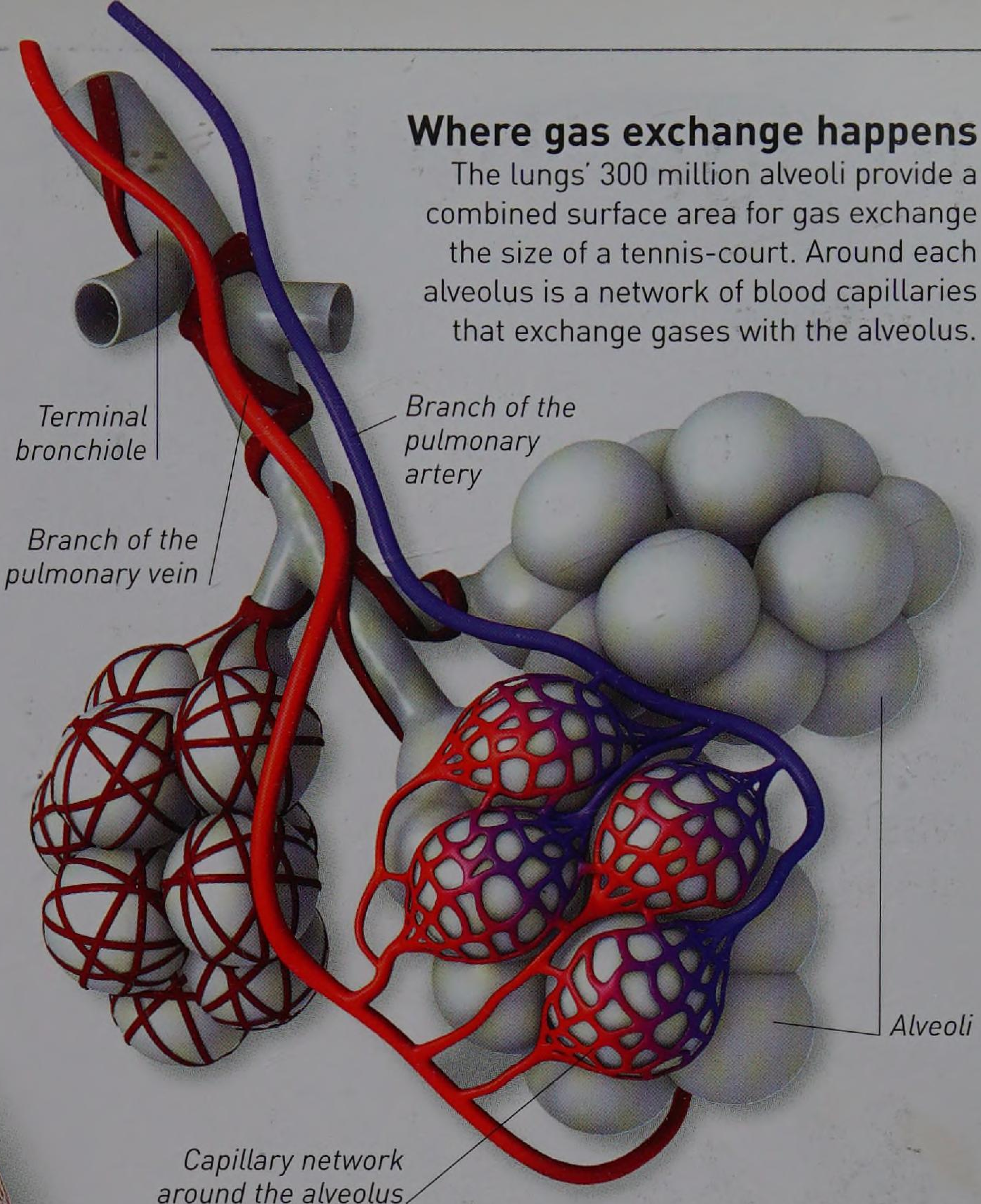
Micro-bubbles

This SEM shows red blood cells in a tiny artery in lung tissue. Surrounding the blood vessel are air-filled, bubble-like alveoli, each measuring less than 0.1 mm (0.004 in) across.



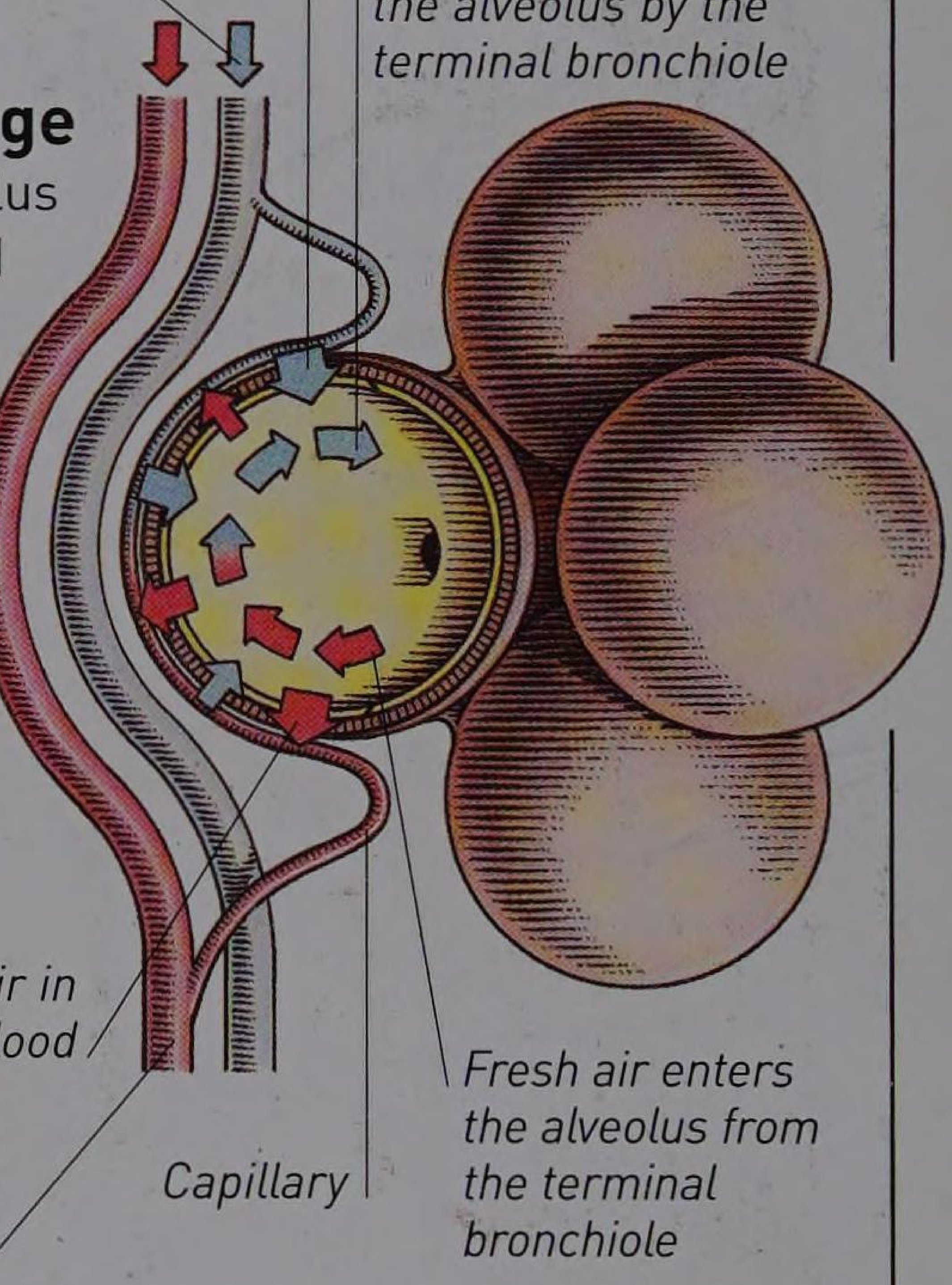
Where gas exchange happens

The lungs' 300 million alveoli provide a combined surface area for gas exchange the size of a tennis-court. Around each alveolus is a network of blood capillaries that exchange gases with the alveolus.



Gas exchange

The walls of an alveolus and the capillary around it are just 0.001 mm (0.00004 in) thick. Oxygen from the alveolus passes into the blood. Carbon dioxide moves in the opposite direction.

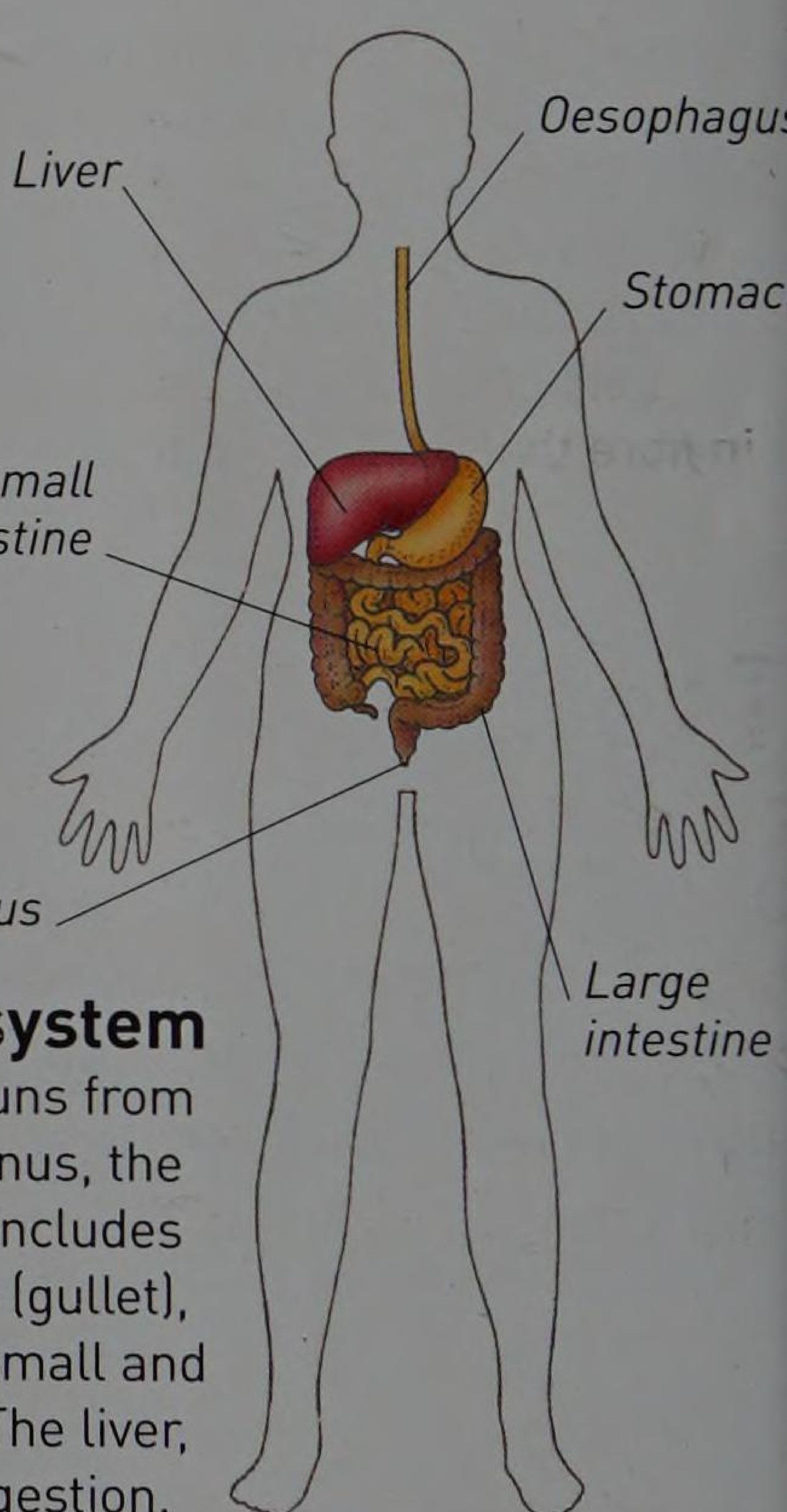


Lungs and heart

The right lung (here cut away to reveal its airways) has three lobes. The left lung has two, and leaves space for the heart. Oxygen-poor blood flows a short distance from the right side of the heart along the pulmonary arteries to the lungs, where it is recharged with oxygen and discharges carbon dioxide. The oxygen-rich blood travels along the pulmonary veins to the heart's left side and is then pumped around the whole body.

Eating

Eating food is essential for life. Food supplies the nutrients – a mixture of carbohydrates, proteins, fats, and other substances – that give the body energy and provide the building blocks for growth and repair. To release these nutrients, food must be processed both mechanically and chemically, by chewing, swallowing, and digesting.

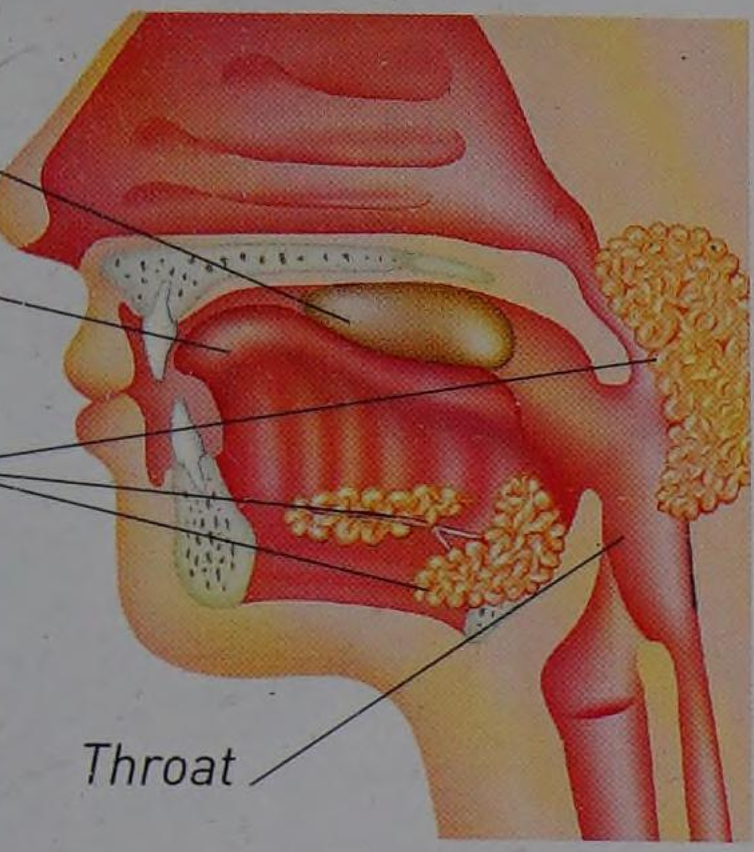


Digestive system

A long tube that runs from the mouth to the anus, the digestive system includes the oesophagus (gullet), stomach, and small and large intestines. The liver, too, is linked to digestion.

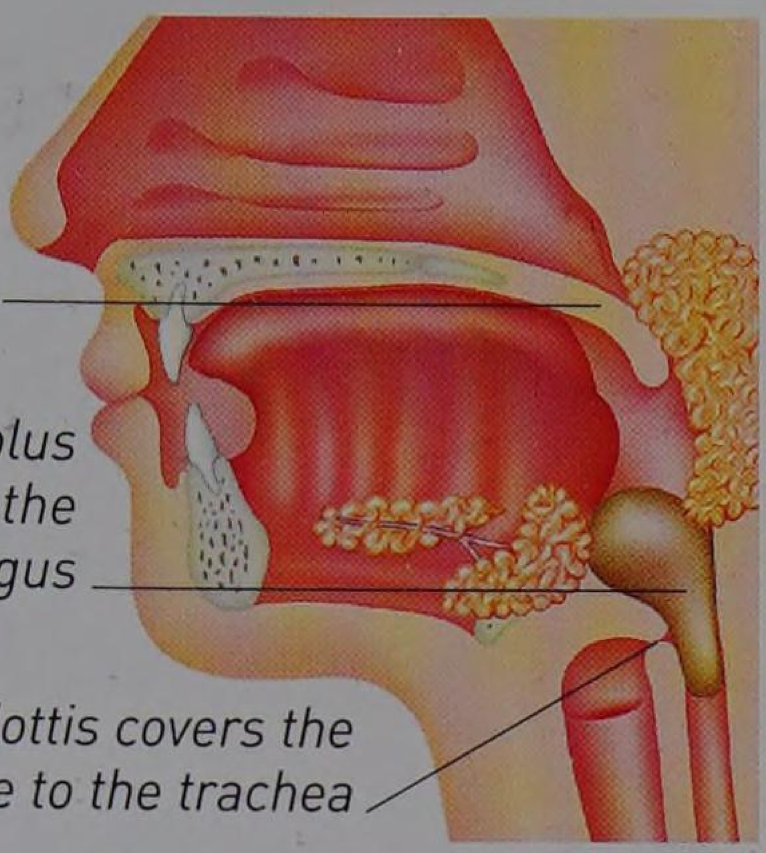
Inside the mouth

When food enters the mouth, taste buds on the tongue sample it to see how delicious or unpleasant it is. As teeth cut and crush the food, salivary glands squirt watery saliva along ducts into the mouth, to bind and lubricate the food particles together. Saliva also contains an enzyme that starts breaking down starch in the food.



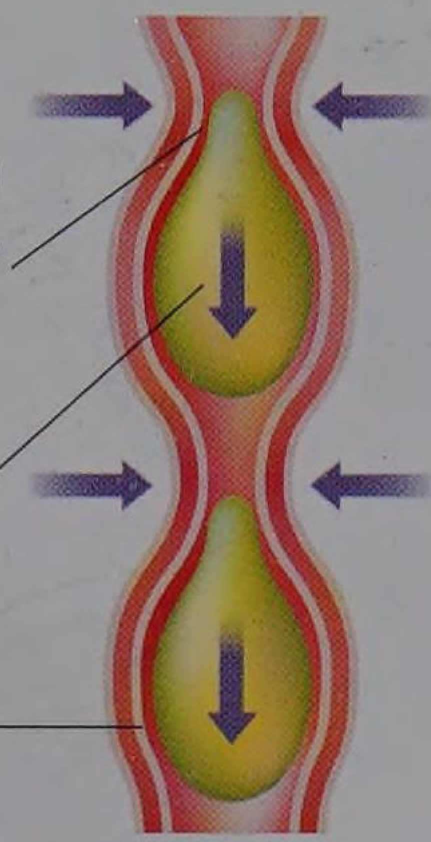
Chewing a mouthful

As we chew, our teeth cut and crush food into small particles. Our tongue mixes the food with the sticky mucus in saliva to form a compact, slippery bolus, or ball of food, and pushes it backwards into the throat.



Swallowing

The tongue pushing back triggers the muscles in the throat to contract, moving the bolus into the oesophagus. The soft palate and epiglottis stop food entering the nasal cavity and trachea (windpipe).



Peristalsis

Peristalsis, or waves of muscle contractions, squeezes the bolus down the oesophagus to the stomach, and also through the intestines.

A balanced diet

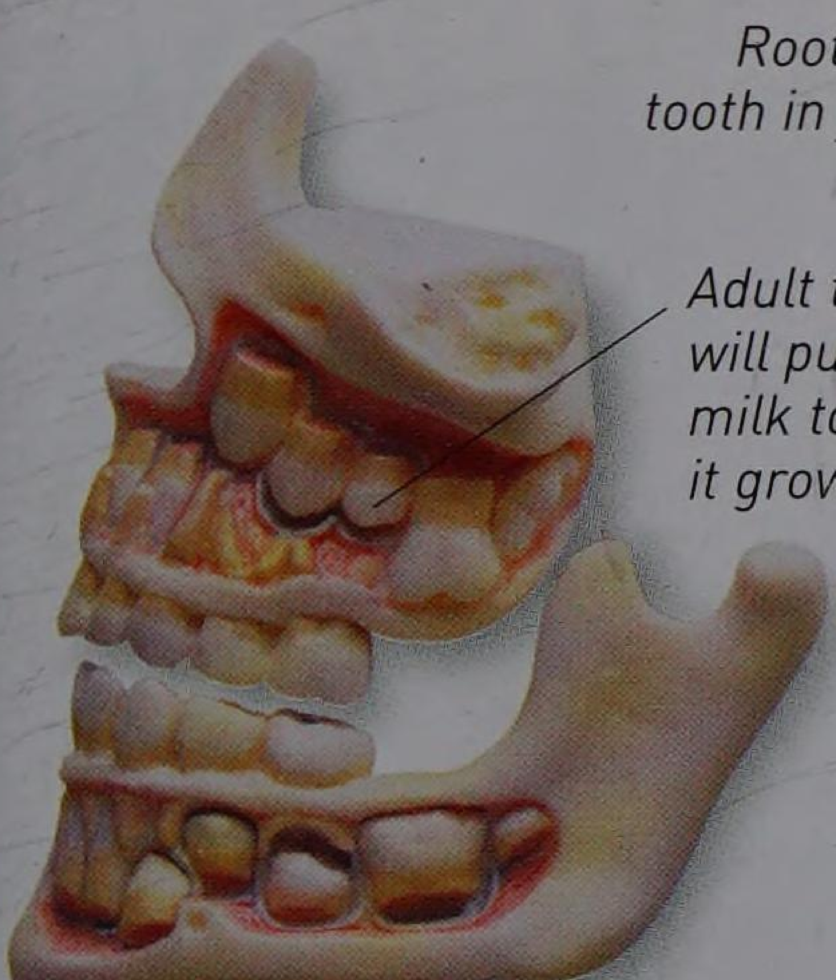
This meal includes the six main nutrients we need from our food. Rice contains carbohydrates (starches and sugars) for energy. Fish and meat contain proteins that build and maintain the body, plus a little fat, for energy. Vegetables (and fruit) are rich in vitamins and minerals that help cells to work well, and in fibre that helps the intestinal muscles work better.

Energy release

Running, like any physical activity, requires the energy that comes from food. The digestive process converts food starches into sugars and fats into fatty acids. Broken down inside muscle cells, these fuels release energy for movement.

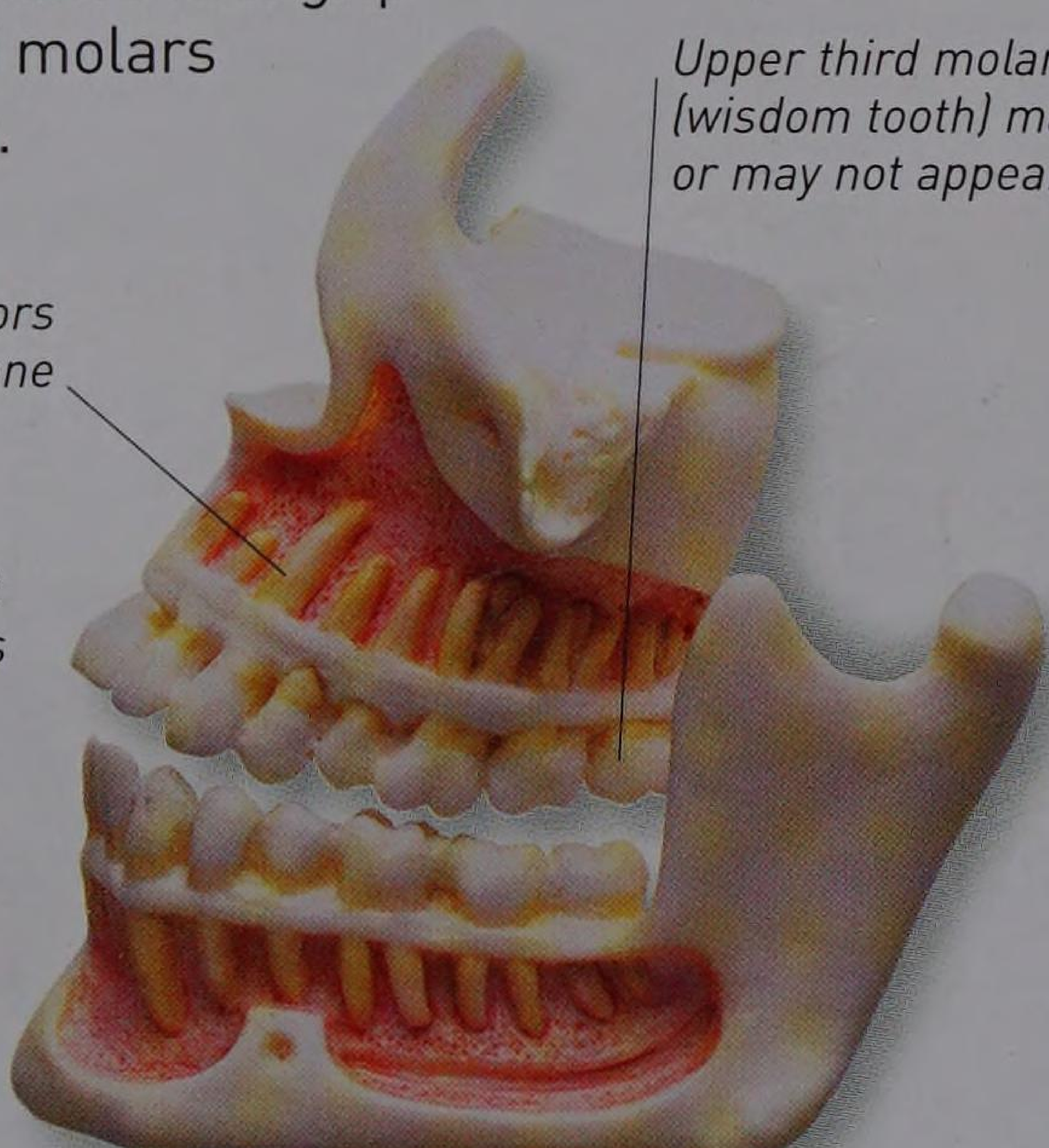
Teeth

Our teeth break up food to make it easier to swallow and digest. During childhood, milk teeth are replaced by a larger set of adult, or permanent, teeth. These include chisel-like incisors that cut and slice at the front, pointed canines that grip and tear, and flat premolars and molars that crush and grind at the back.



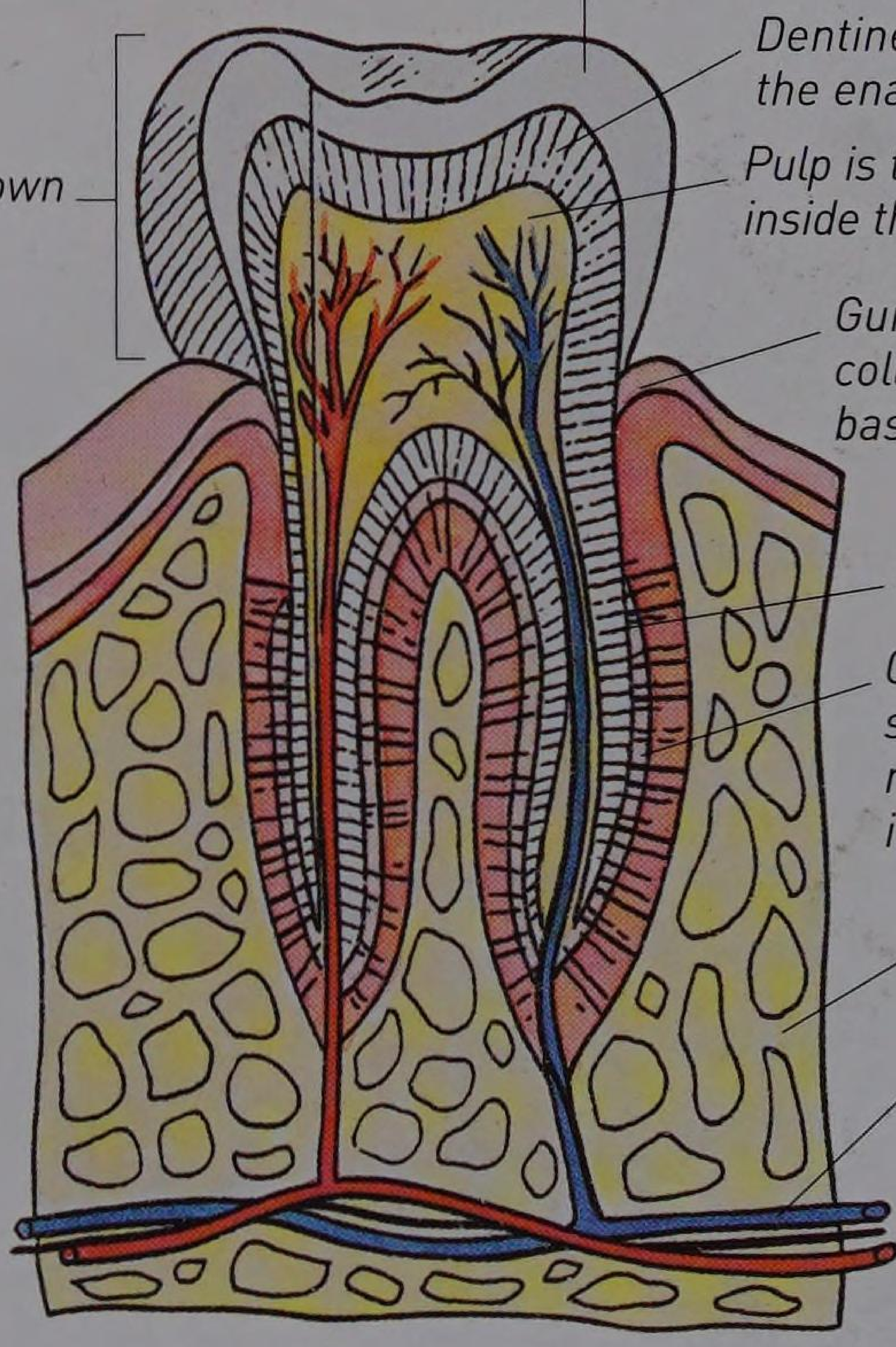
Five-year teeth

The first 20 milk teeth appear from the age of six months. From about six years they begin to fall out.



Full set of adult teeth

By early adulthood, all 32 adult teeth have come through. Each half jaw has two incisors, one canine, two premolars, and three molars.



Inside a tooth

Bone-like dentine forms the tooth's root and supports a rock-hard crown of non-living enamel for grinding up food. The central cavity contains living pulp tissue fed by blood vessels and by nerve endings that sense pressure as we bite and chew.

Digestion

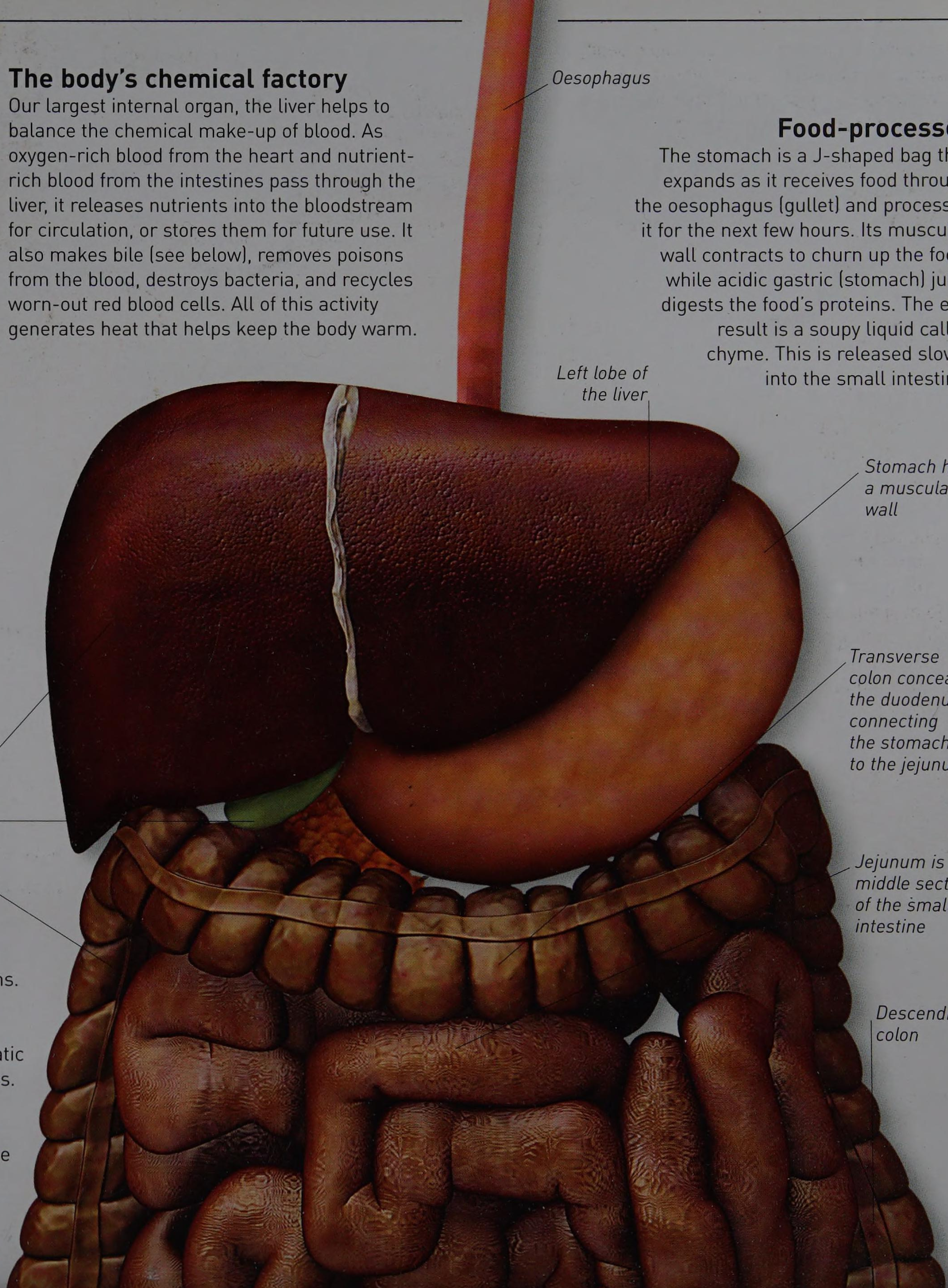
After swallowing, it takes about ten seconds for chewed food to reach the stomach, where digestion really gets under way. The stomach starts to break down food with enzymes (chemical digesters) and churns it into liquid chyme, which it releases slowly into the small intestine. Here, further enzymes digest food into its simplest components. These nutrients are then absorbed into the bloodstream and circulated to the body's cells.

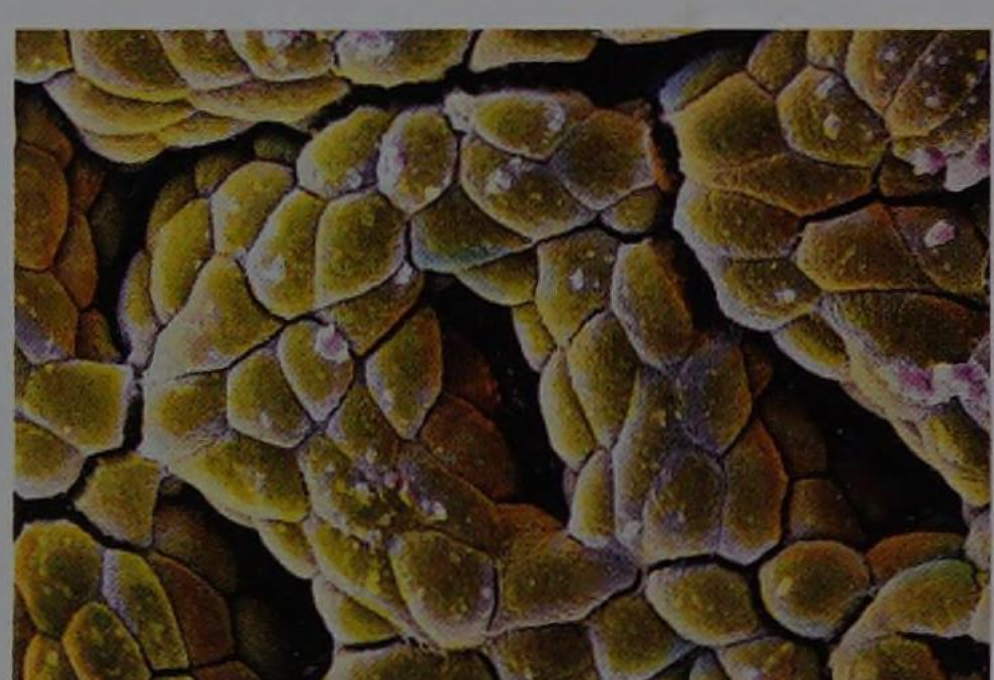
The body's chemical factory

Our largest internal organ, the liver helps to balance the chemical make-up of blood. As oxygen-rich blood from the heart and nutrient-rich blood from the intestines pass through the liver, it releases nutrients into the bloodstream for circulation, or stores them for future use. It also makes bile (see below), removes poisons from the blood, destroys bacteria, and recycles worn-out red blood cells. All of this activity generates heat that helps keep the body warm.

Food-processor

The stomach is a J-shaped bag that expands as it receives food through the oesophagus (gullet) and processes it for the next few hours. Its muscular wall contracts to churn up the food, while acidic gastric (stomach) juice digests the food's proteins. The end result is a soupy liquid called chyme. This is released slowly into the small intestine.





Gastric pits

Millions of gastric pits dot the stomach's lining. Through these tiny holes, gastric glands release gastric juice into the stomach. The juice produces an enzyme that digests the proteins in food. Mucus in the juice coats the stomach lining and prevents the juice from digesting the lining itself.

The intestines

The small intestine is about 6 m (20 ft) long and has three sections. The short duodenum receives chyme from the stomach and digestive fluids (bile and pancreatic juice) from the liver and pancreas. In the jejunum and ileum, digestion is completed and nutrients are absorbed. The large intestine is just 1.5 m (5 ft) long. Here, watery waste from the ileum dries out as it passes along the colon and forms faeces to store in the rectum.

Intestinal lining

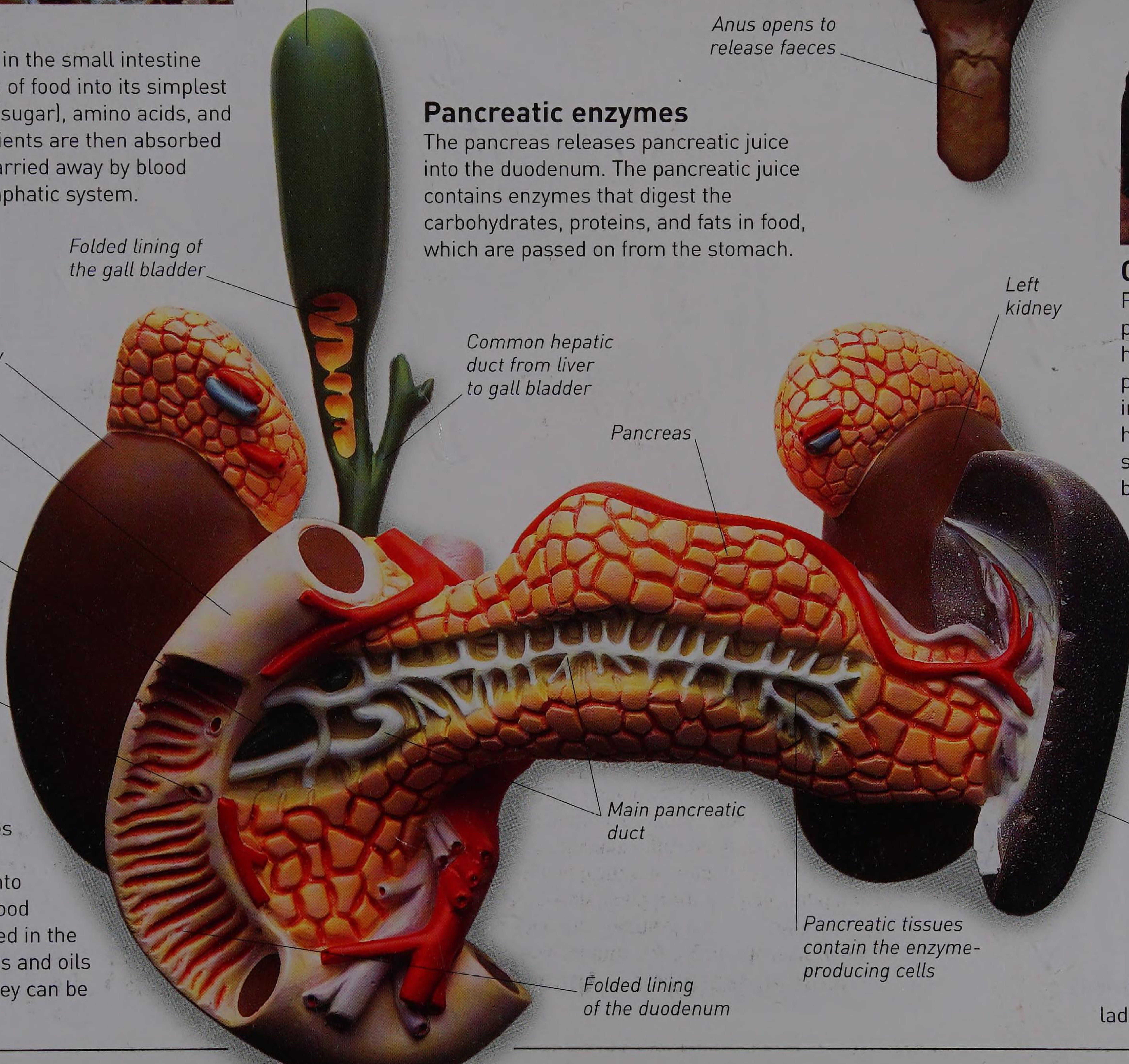
Enzymes on these villi in the small intestine complete the digestion of food into its simplest components: glucose (sugar), amino acids, and fatty acids. Those nutrients are then absorbed through the villi and carried away by blood capillaries and the lymphatic system.

Pancreatic enzymes

The pancreas releases pancreatic juice into the duodenum. The pancreatic juice contains enzymes that digest the carbohydrates, proteins, and fats in food, which are passed on from the stomach.

Claude Bernard

French scientist Claude Bernard (1813–78) proved that substances from the pancreas helped break down fat, and that the main processes of digestion occur in the small intestine. He also pioneered the idea of homeostasis, that constant conditions, such as temperature or correct water balance, are maintained inside the body.



Gall bladder and bile

The gall bladder is a stretchy bag that stores green-coloured, liquid bile, then releases it into the duodenum when food arrives. Bile is produced in the liver and breaks up fats and oils into tiny droplets so they can be digested more rapidly.

Digestive waste disposal

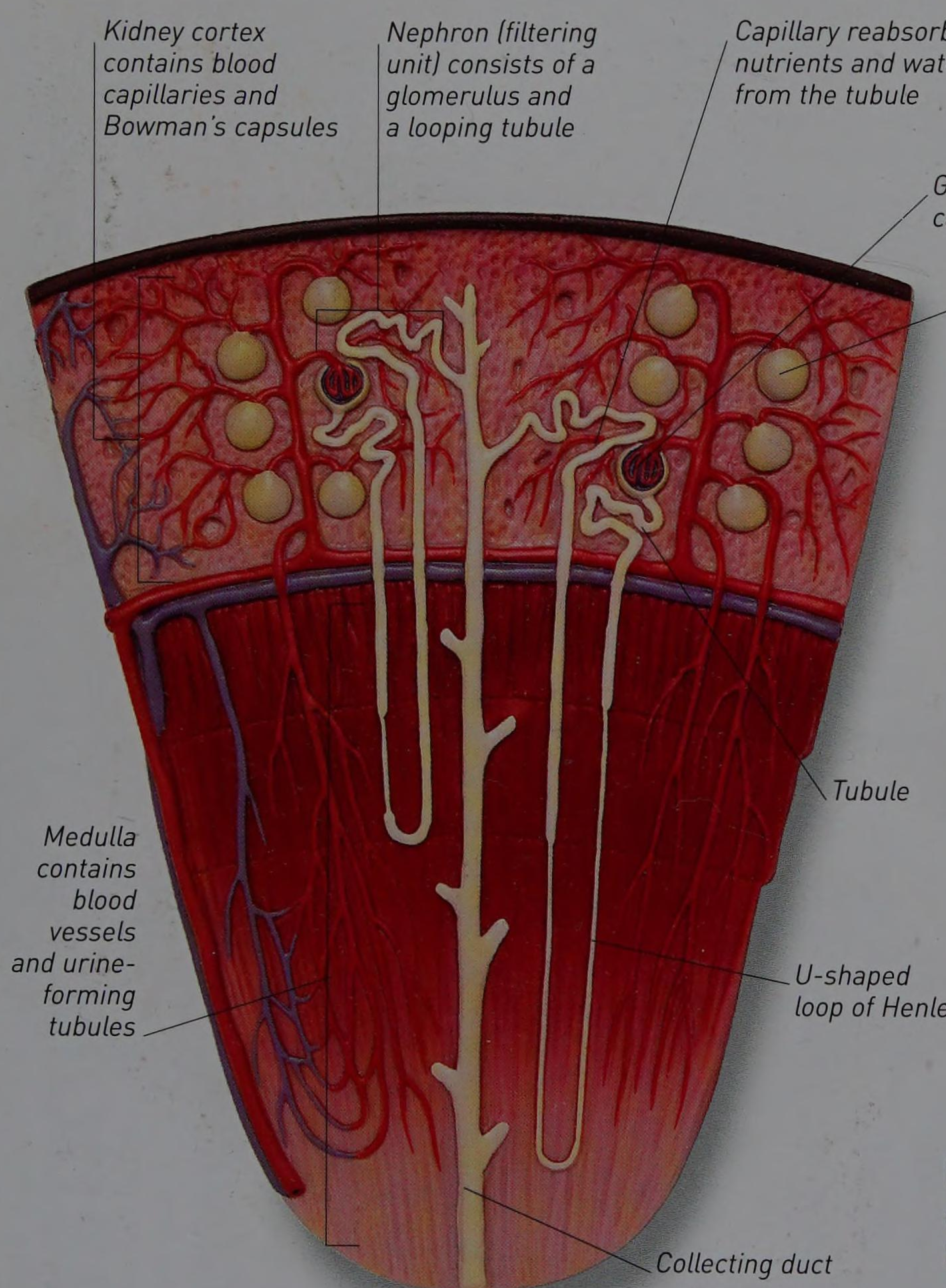
After eating, it takes 20–44 hours for the indigestible waste, in the form of bacteria-laden faeces, to reach the rectum for release.

Bladder control
When a baby's bladder is full of urine, the stretch receptors in its muscular wall automatically tell it to empty. Young children learn to control this reflex action.

Waste disposal

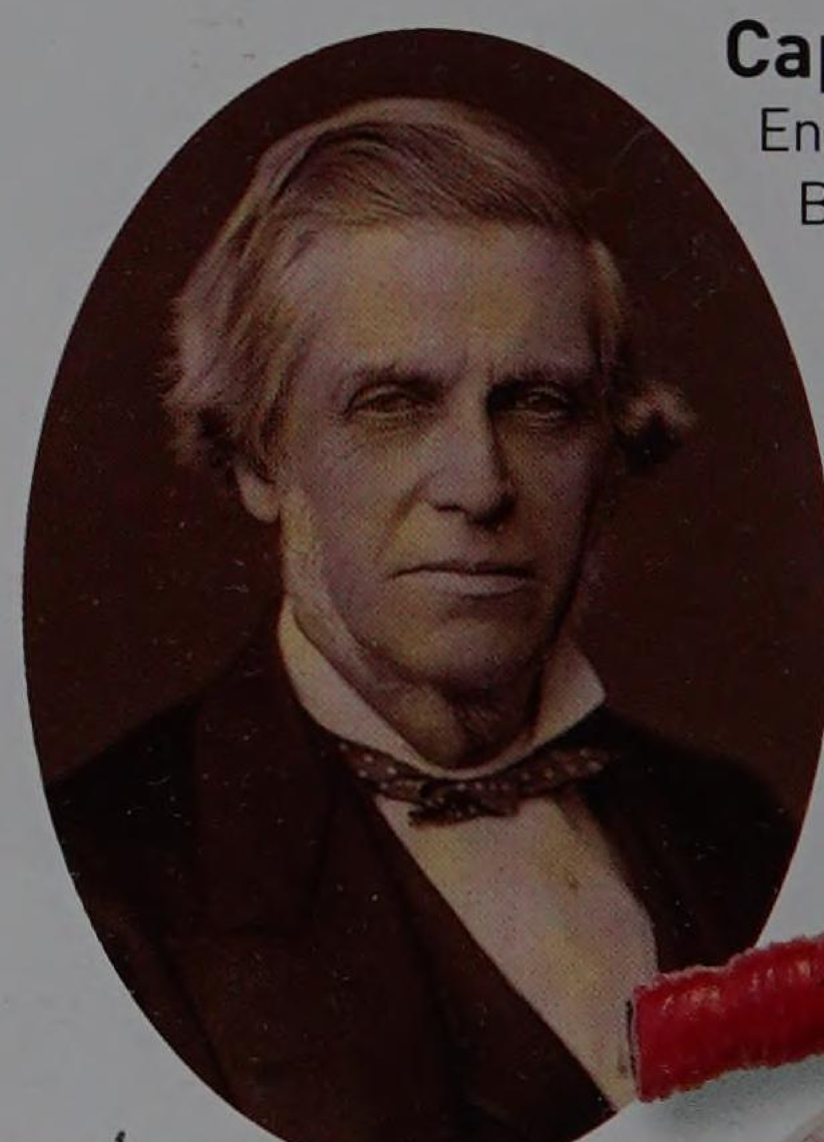
Body cells continually release waste substances, such as urea made by the liver, into the bloodstream. If left to build up, they would poison the body. The urinary system disposes of waste by cleansing the blood as it passes through a pair of kidneys. It also removes excess water to ensure the body's water content stays the same.

Giant of ancient Greece
The Greek philosopher Aristotle (384–322 BCE) challenged ideas about anatomy by looking inside the real bodies of animals and humans and recording what he saw. He provided the first descriptions of the urinary system and how it works.



Filtering unit
Each kidney's blood-filtering unit, or nephron, links to a long tubule. This loops from the cortex to the medulla and back, then joins a collecting duct. As fluid filtered from blood passes along the nephron, useful substances are absorbed back into the bloodstream, leaving waste urine to flow into the collecting duct.

Capsules and loops
English surgeon and scientist William Bowman (1816–92) identified the capsule that bears his name. The U-shaped loop of Henle was later described by the German anatomist Jakob Henle (1809–85).



William Bowman

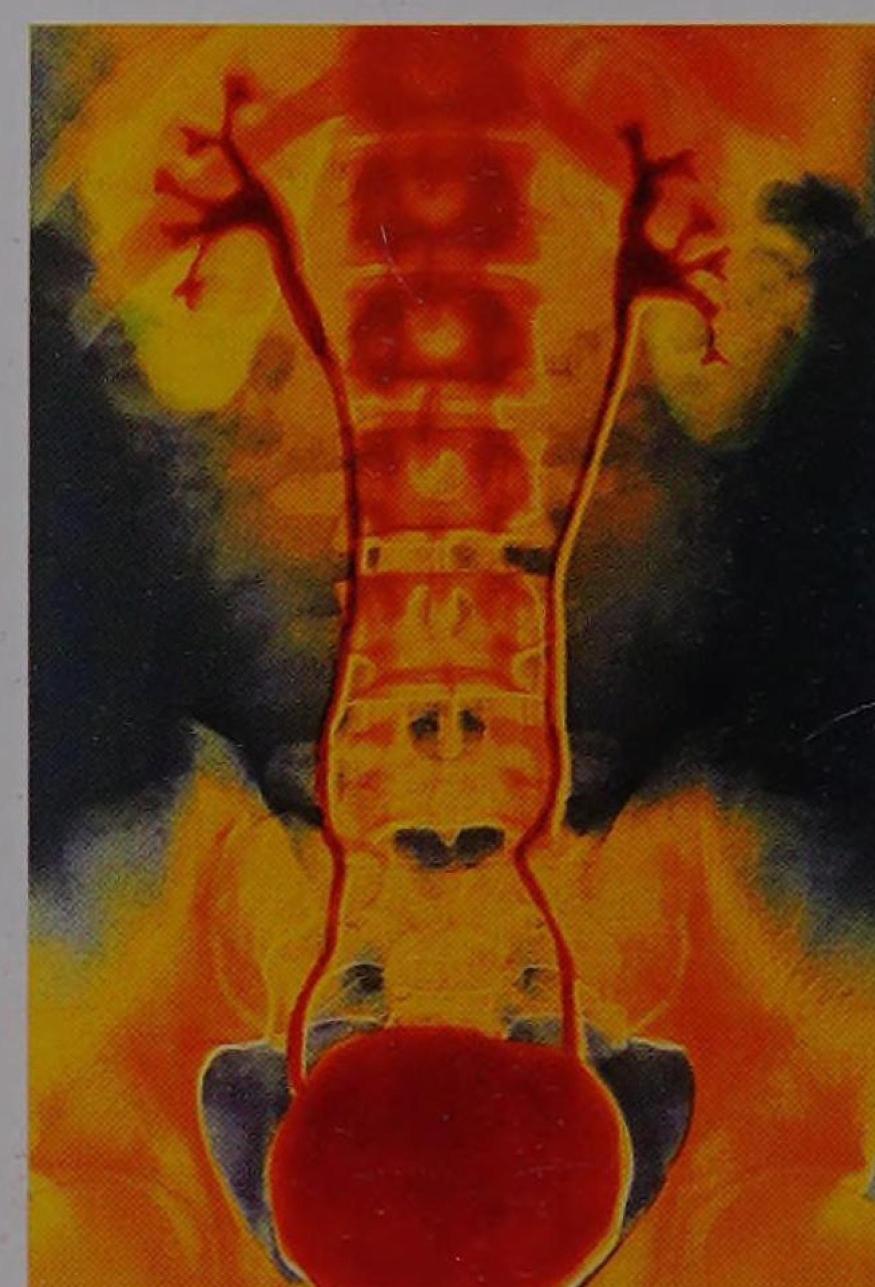
Bowman's capsule
Each capsule surrounds a glomerulus, or cluster of capillaries. They filter the blood and produce a fluid. It contains not only waste, but also substances such as glucose (sugar), which are useful to the body.

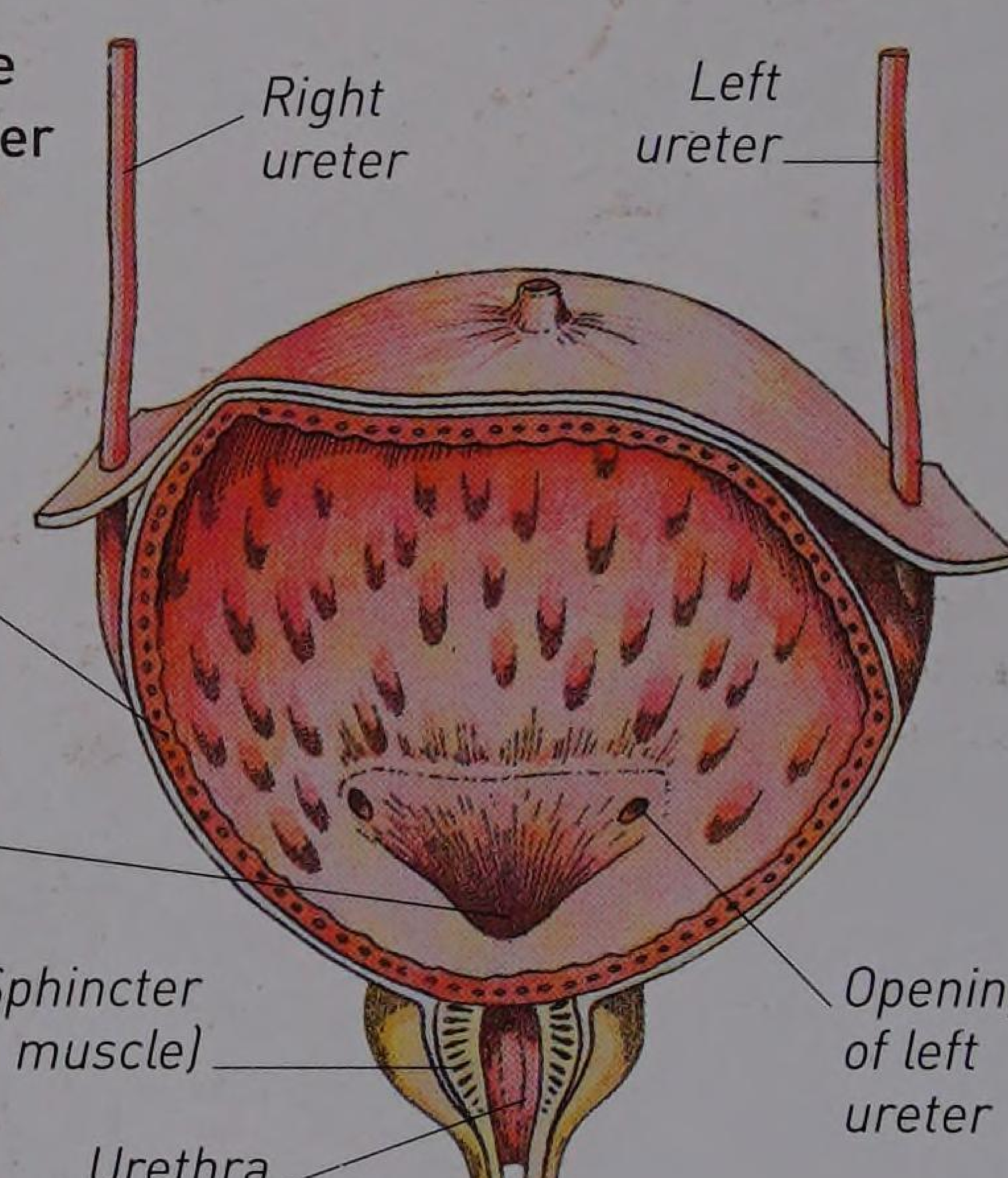
Urinary system

The two kidneys contain two million nephrons that process 1,750 litres (385 gallons) of blood per day, producing about 1.5 litres (2.5 pints) of urine. The urine goes from a kidney's hollow pelvis into a ureter. This long tube's muscular walls squeeze urine down to the bag-like bladder, which stores the urine until a person wants to urinate. A ring of muscle, the sphincter, mostly holds the bladder exit tightly closed. When the sphincter is relaxed, urine leaves the body through a tube called the urethra.

Urinary X-ray

Using a special red dye injected into the bloodstream, this X-ray shows the flow of urine through the body. The dye is filtered out of the blood into urine through the kidney's nephrons. Then it passes into the pelvis at the centre of each kidney, down the ureters, and into the bladder.



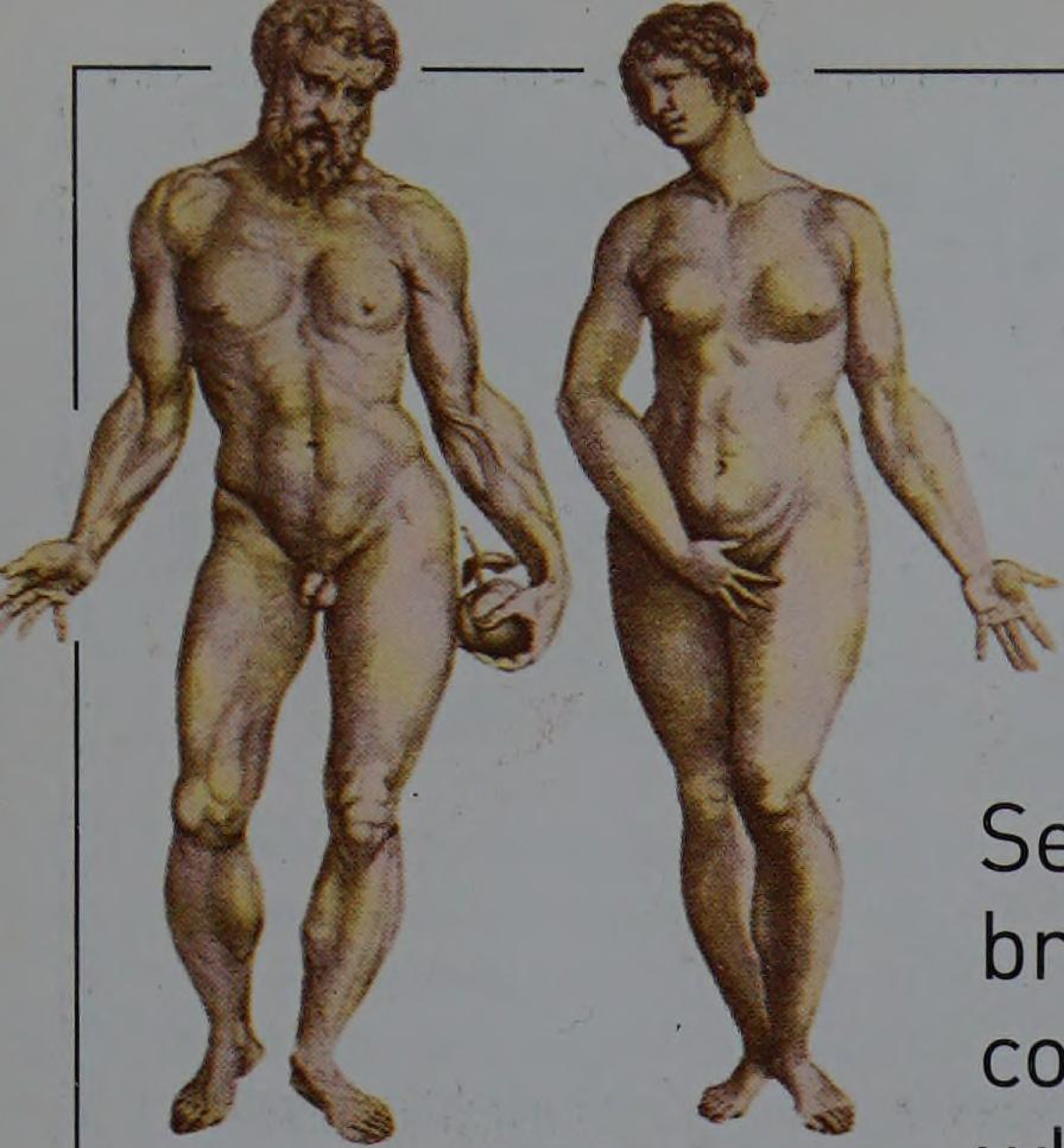


Bladder control

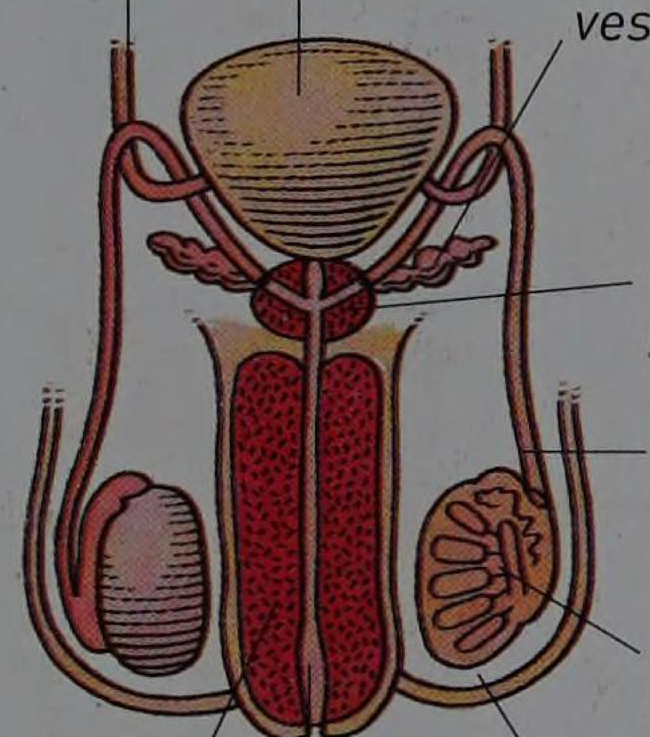
The bladder's elastic, muscular wall expands as it fills with urine. Receptors send signals to the brain, triggering the need to urinate. As the sphincter relaxes, the bladder muscles squeeze the urine out through the urethra.

Male and female

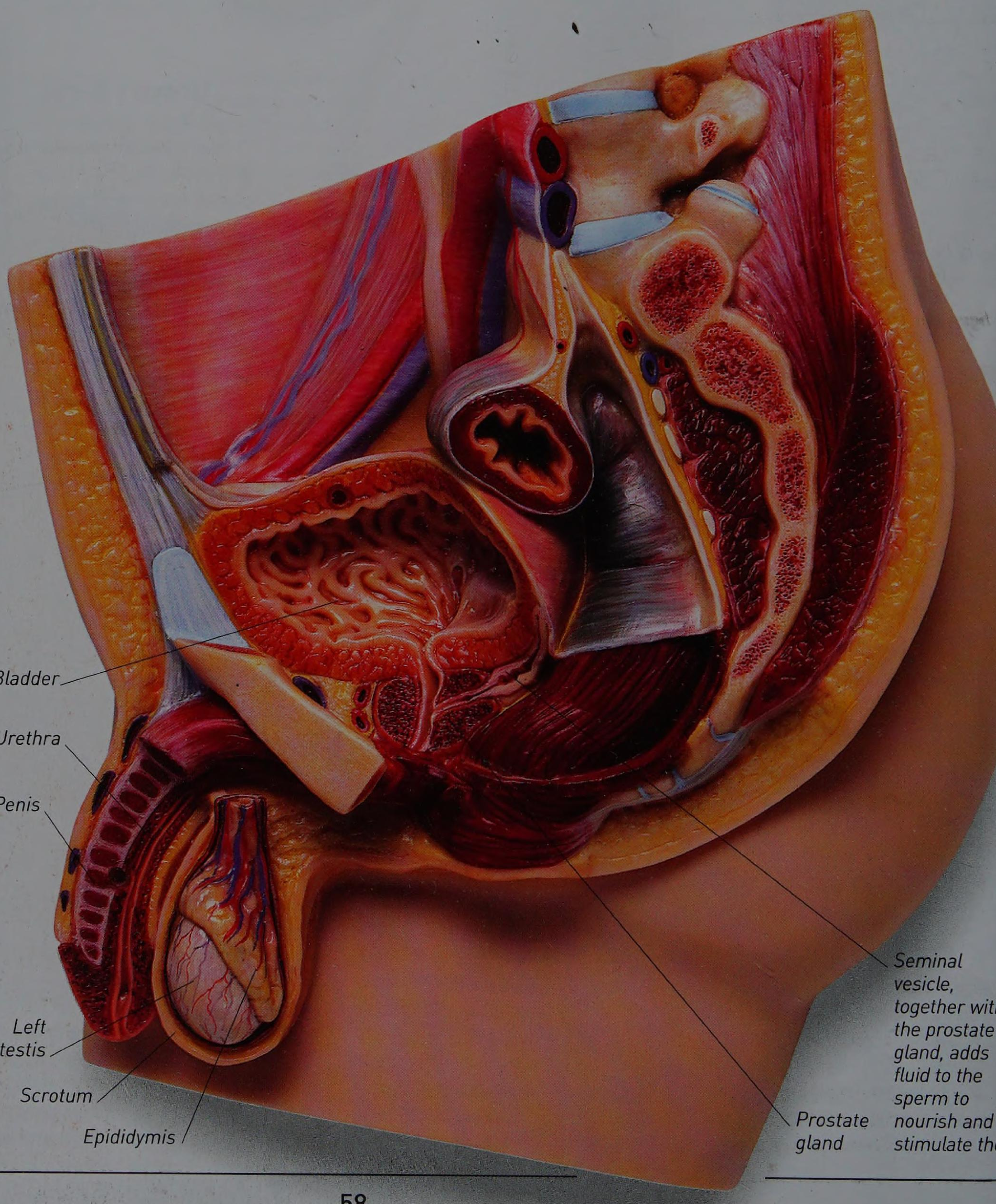
Like all life forms, humans reproduce to pass on their genes and continue the cycle of life. Male and female reproductive systems produce different sex cells. Sexual intercourse (sex) between a man and a woman brings her eggs and his sperm together. These sex cells contain half of each partner's DNA (genetic instructions), which combine during fertilization inside the woman's body to create a new life. Her uterus then provides the place where the baby will develop.



External features
A 1543 guide to anatomy by Vesalius shows the male is more muscular than the female, with wide shoulders, narrow hips, and more facial and body hair. She is more rounded by body fat around the thighs and abdomen, with wide hips and developed breasts.



Front view of the male reproductive system



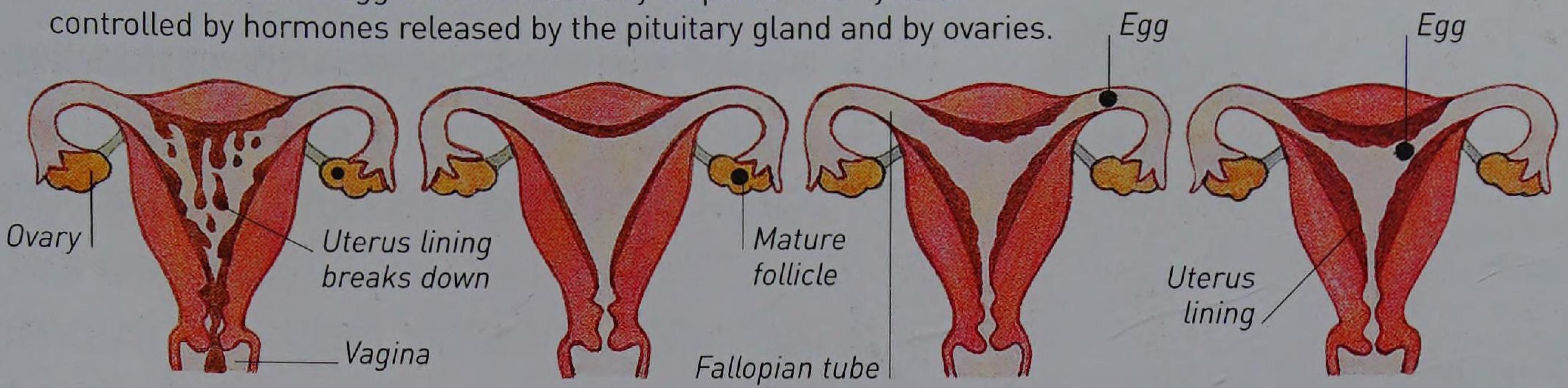
Male reproductive organs
This side-view shows one of two testes that hang outside the body in a skin bag called the scrotum. Inside each testis, a hormone stimulates sperm production throughout a man's adult life. During sex, muscle contractions push sperm along two sperm ducts into the urethra and out of the penis.

Regnier de Graaf

Dutch physician and anatomist Regnier de Graaf (1641–73) did detailed research on the male and female reproductive systems. In the female system, he identified the ovaries and described the tiny bubbles on the ovary's surface that appear each month. Later scientists realized that each bubble is a ripe follicle with the much smaller egg contained within it.

The menstrual cycle

Every 28 days, in a woman's menstrual (monthly) cycle, or period, an egg is released from an ovary and the lining of the uterus thickens in order to receive the egg if it is fertilized by a sperm. The cycle is controlled by hormones released by the pituitary gland and by ovaries.

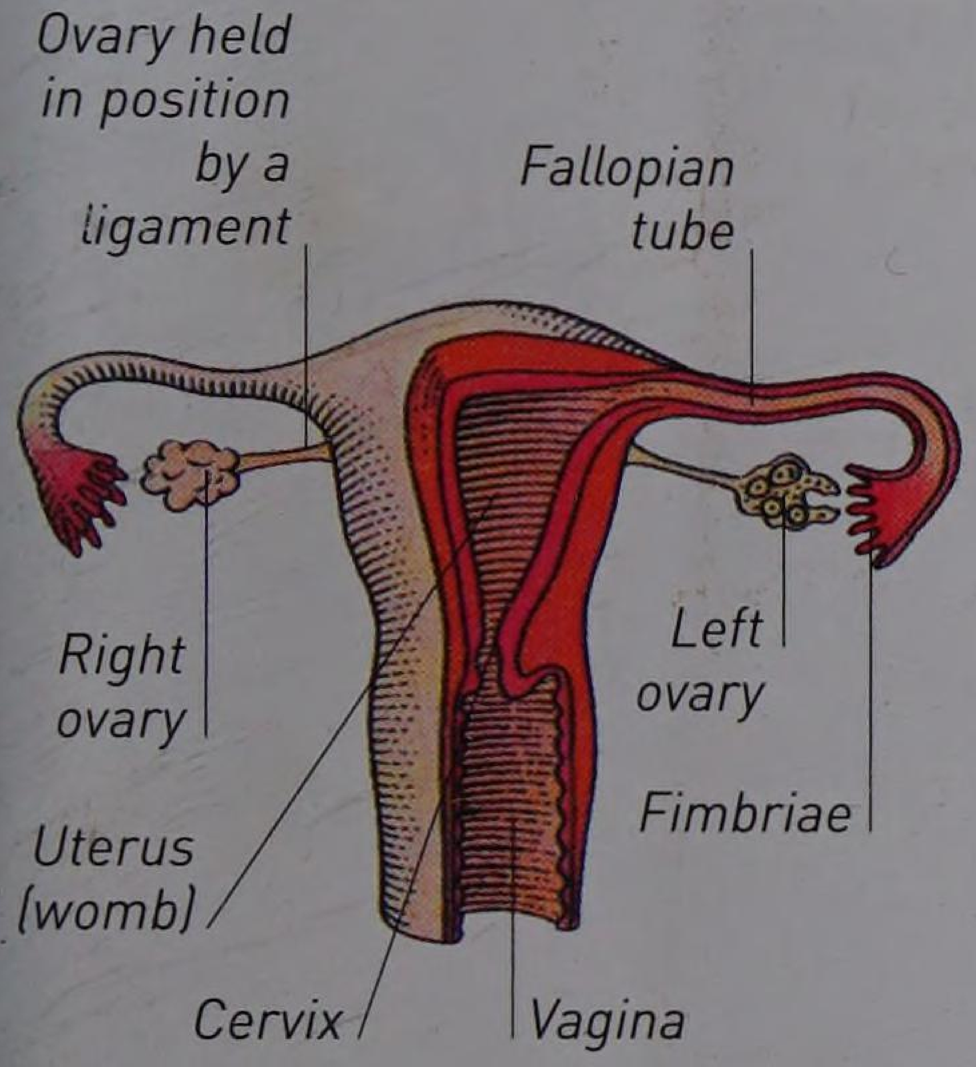


1 First week
The uterus lining, which thickened in the previous period, breaks down and is lost as blood-flow through the vagina.

2 Second week
An egg-containing follicle near the ovary's surface swells as it ripens. The uterus lining begins to grow and thicken again.

3 Third week
Ovulation occurs when the mature follicle releases its egg. The egg is moved along the fallopian tube towards the uterus.

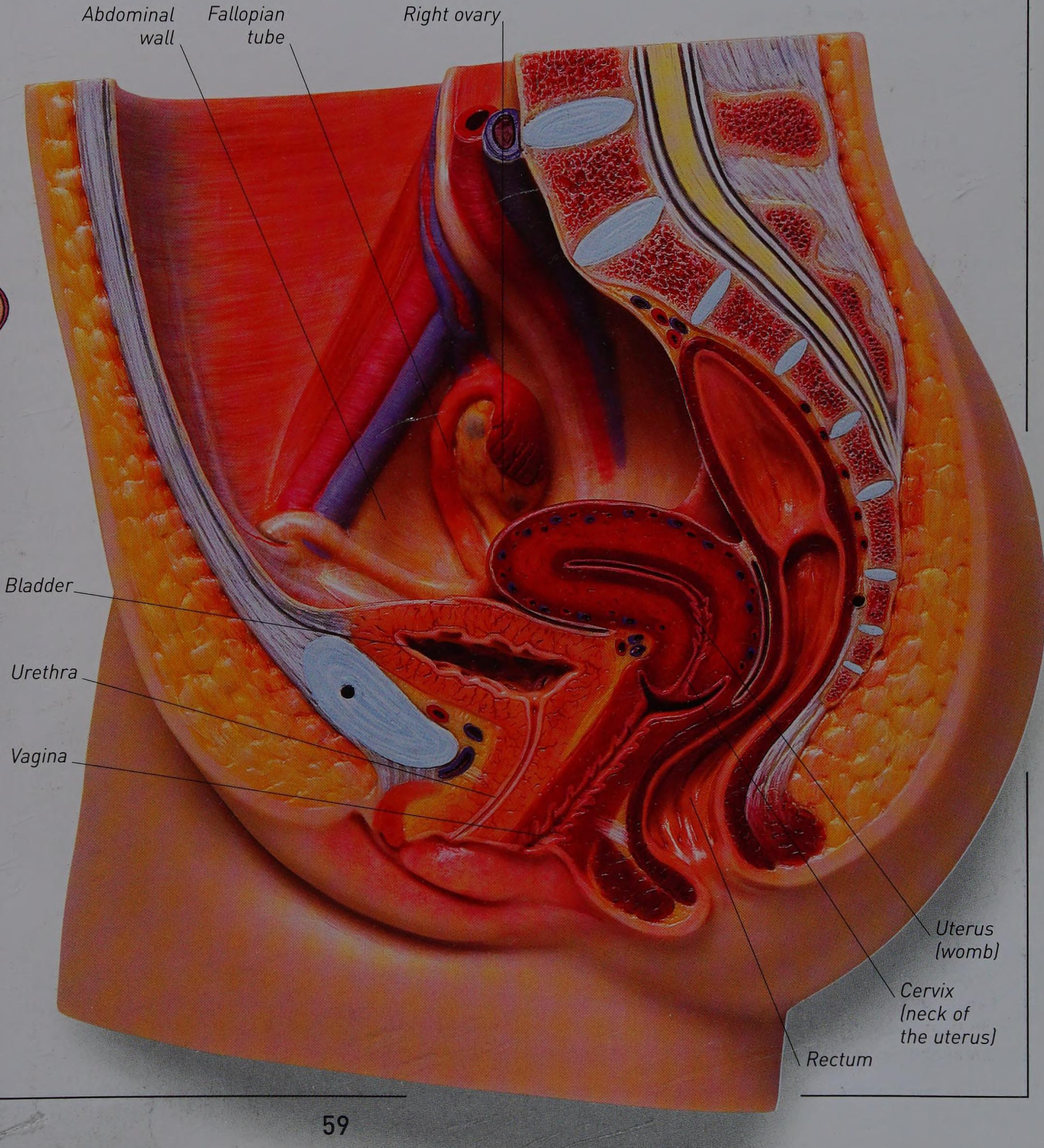
4 Fourth week
The uterus lining is thick and blood-rich. If the egg is fertilized, it sinks into the lining. If not, it is broken down and the cycle begins again.



Front view of the female reproductive system

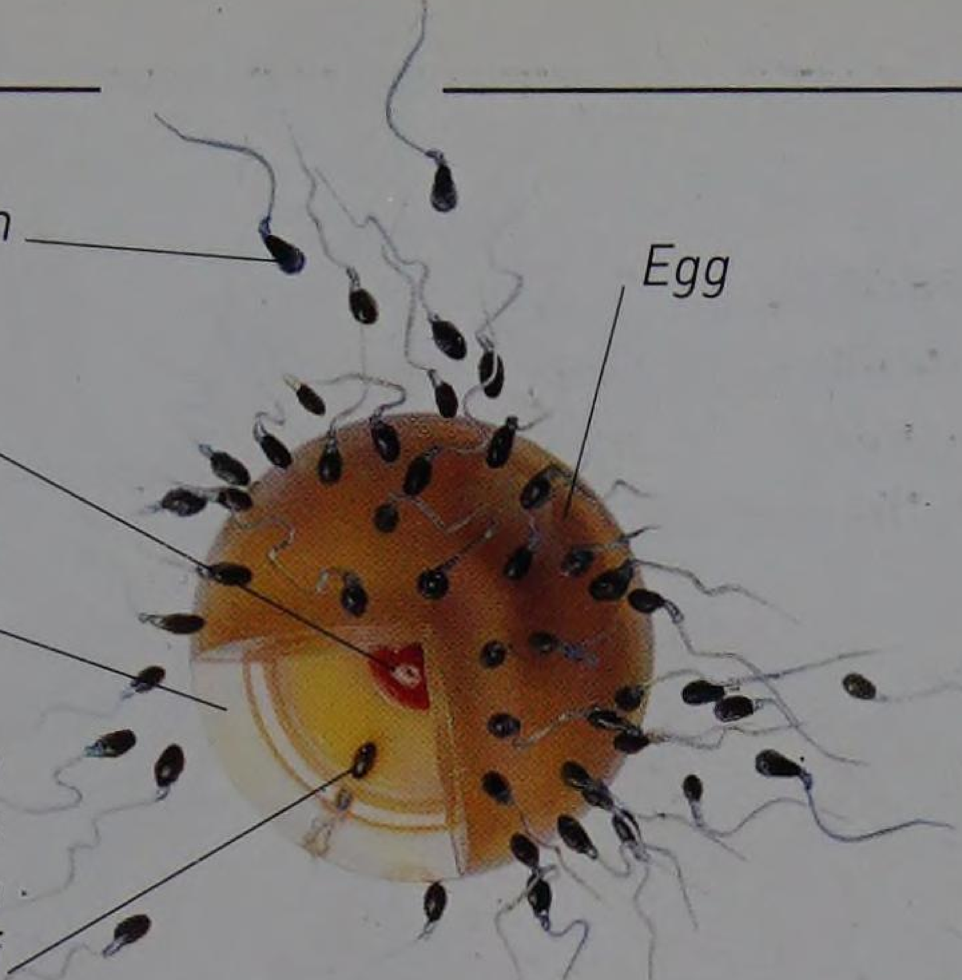
Female reproductive organs

A woman's ovaries release a single mature egg each month during her fertile years. It is wafted by fimbriae into the fallopian tube that leads to the uterus. If the egg meets a sperm soon after its release, the two fuse and fertilization occurs. This results in a baby that grows inside the greatly expanding uterus (womb) and is eventually born through the vagina.



A new life

Fertilization merges the DNA (genetic instructions) carried by a male sperm and female egg. If the fertilized egg, no bigger than the full stop at the end of this sentence, settles in the lining of the woman's uterus, it grows into an embryo and then a fetus. Around 38 weeks after fertilization, the fetus is ready to be born. Muscular contractions in the uterus push the baby out through its mother's vagina, and the newborn baby takes its first breath.



Fertilization of an egg

In this cutaway model, one of the sperm trying to get through the outer covering of the egg has succeeded. Its tail has dropped off, and its head (nucleus) will fuse with, or fertilize, the egg's nucleus. No other sperm can now get through.

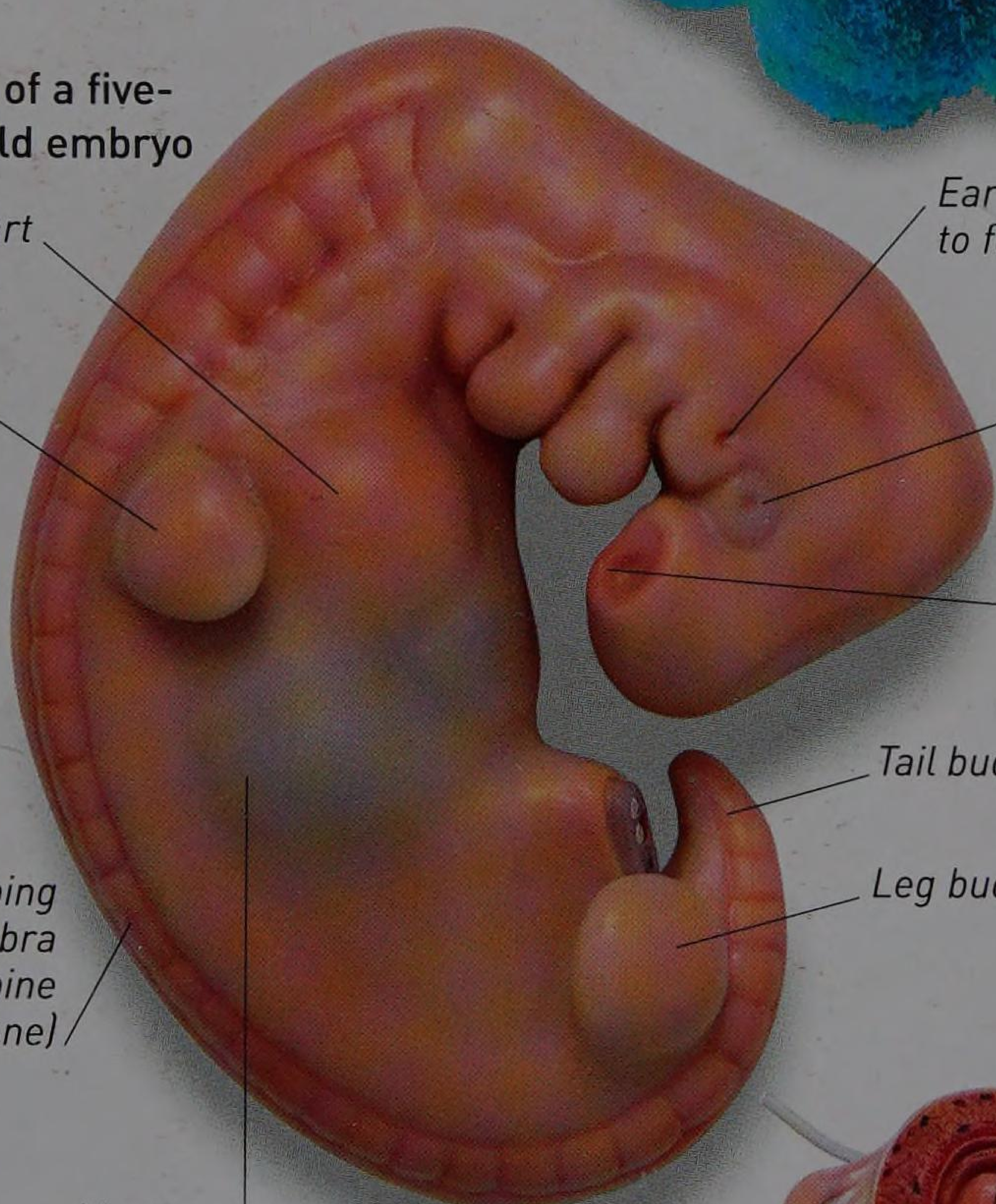
Embryo development

The fertilized egg divides into two cells, then four, eight, and so on. A week after fertilization, it implants in the uterus lining, becoming an embryo. As its cells divide, they form muscle, nerve, and other tissues. By five weeks, the embryo is the size of a pea.

Cluster of 16 cells

First embryologist

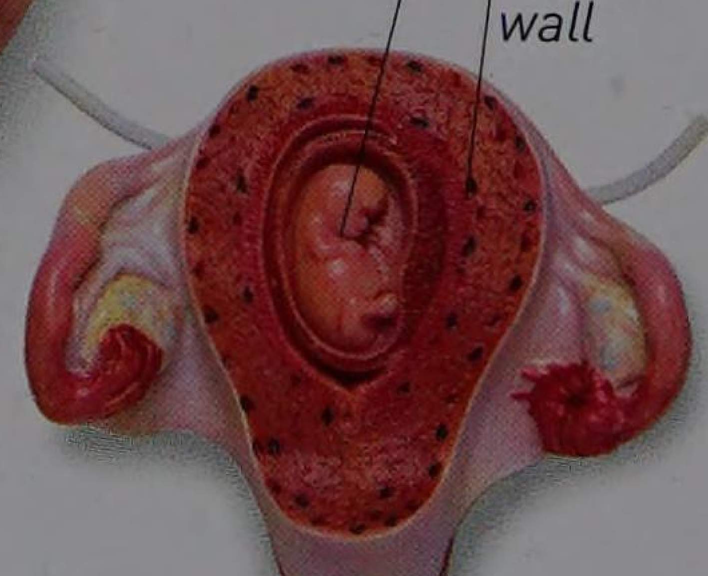
Italian anatomy professor Hieronymus Fabricius (1537–1619) described the development of unborn babies, or embryos, in humans and in other animals. Known as the founder of embryology, he also named the ovary and predicted its function.



Model of a five-week-old embryo

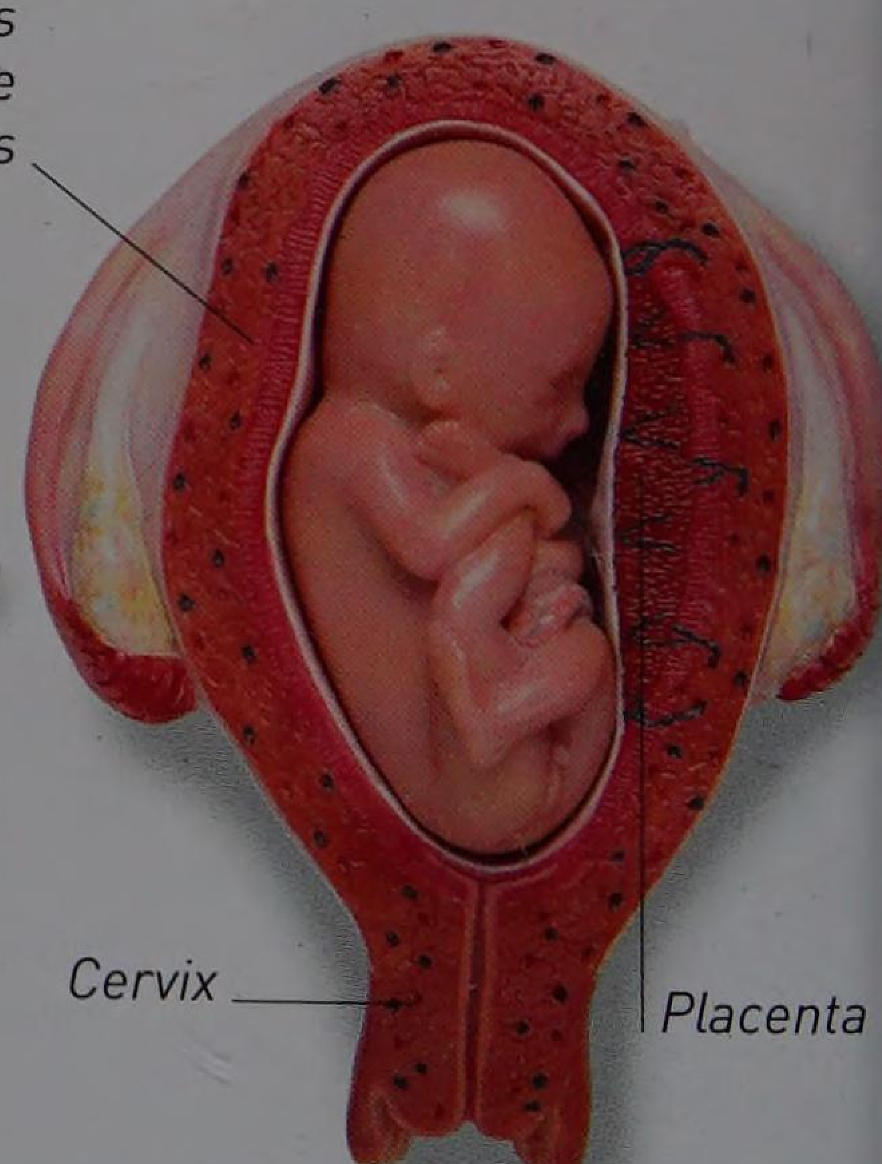
Fetal development

From two months after fertilization through to birth, the baby gradually comes to look human. It is now called a fetus. At two months, it is no bigger than a strawberry but its major organs have formed and its heart is beating. By around nine months, the fetus weighs about 3–4 kg (6.5–9 lb).

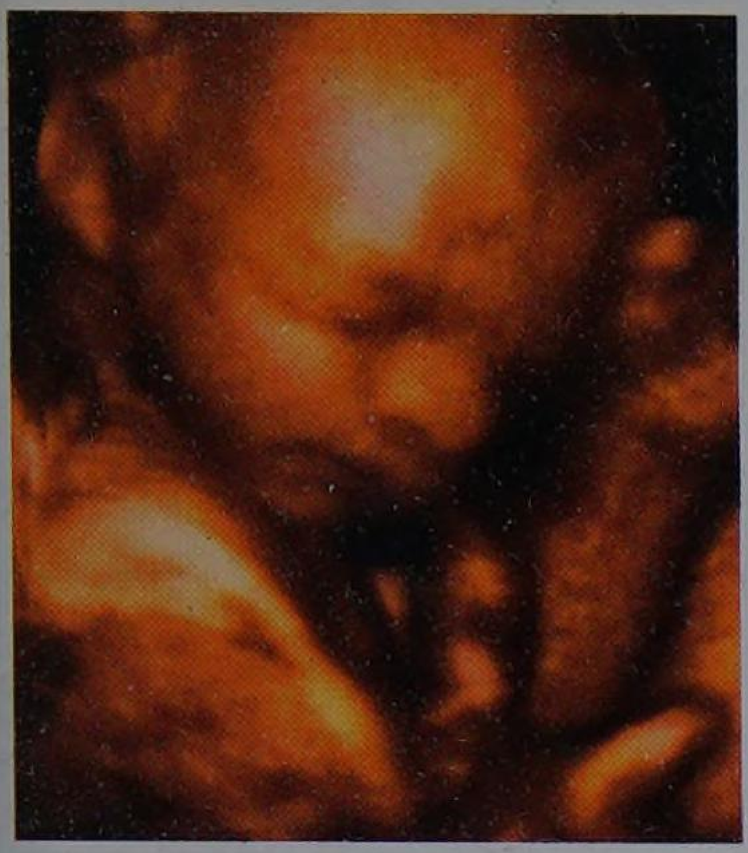


1 Two months The 2.5-cm- (1-in-) long fetus has limbs and its brain is expanding rapidly.

2 Three months About 8 cm (3 in) long, the fetus looks human and has eyes.



3 Five months The fetus is 20 cm (8 in) long and responds to sounds by kicking and turning somersaults.

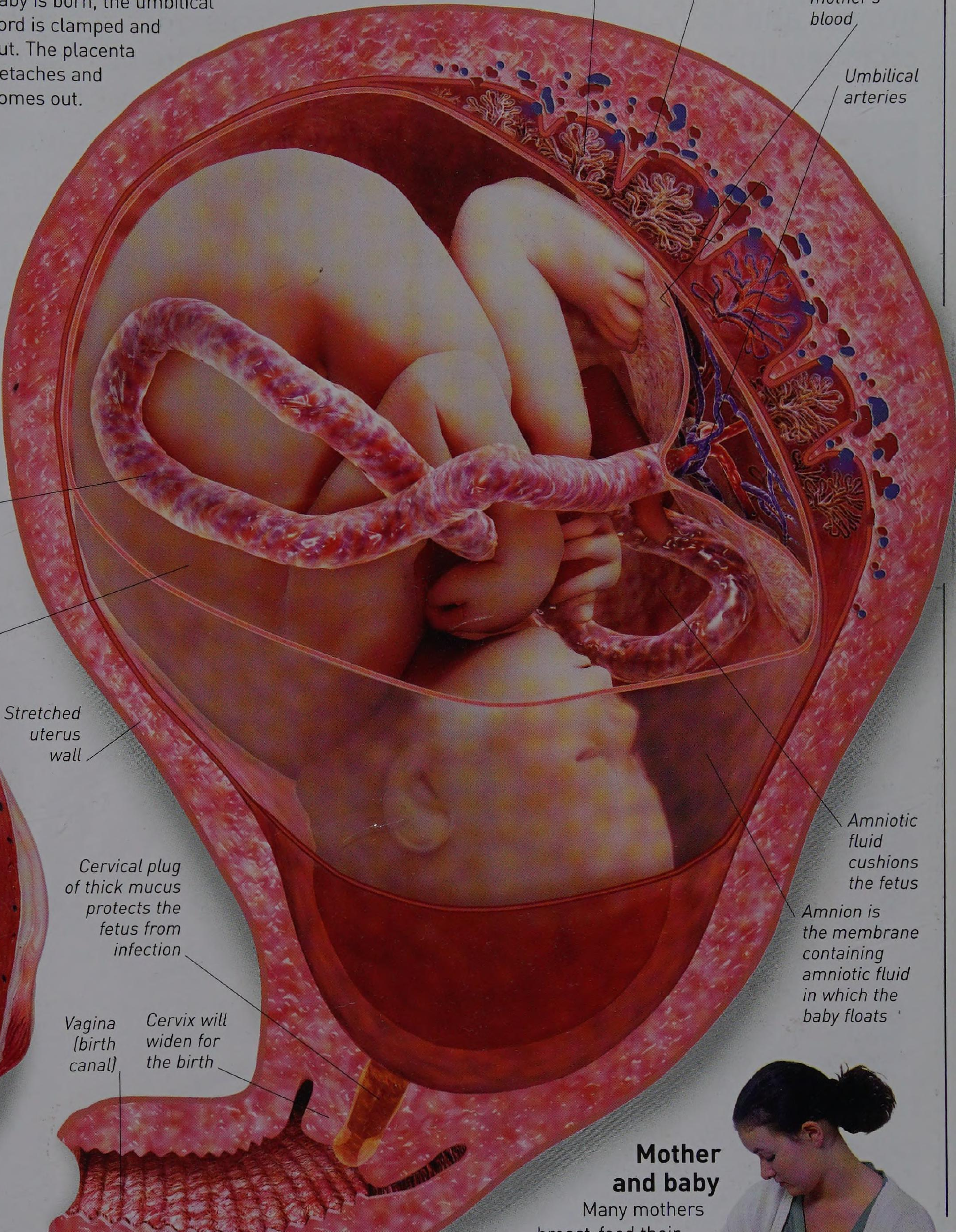


Seeing the fetus

Ultrasound scans carried out after about 11 weeks check all is well with the fetus developing inside the uterus. The scanner beams high-pitched but harmless sound waves into the body, and detects their echoes. A computer displays the echoes as a 3D image.

The placenta

The placenta on the wall of the uterus nourishes the fetus. Inside it, blood vessels from the mother and fetus pass close to each other. This allows oxygen and food to pass from the mother's blood into the blood of the fetus, through the umblical cord. Waste from the fetus flows the other way. After the baby is born, the umbilical cord is clamped and cut. The placenta detaches and comes out.



4 Seven months

Now about 48 cm (19 in) long, the fetus has finger- and toenails, and its eyes are open.

5 Nine months

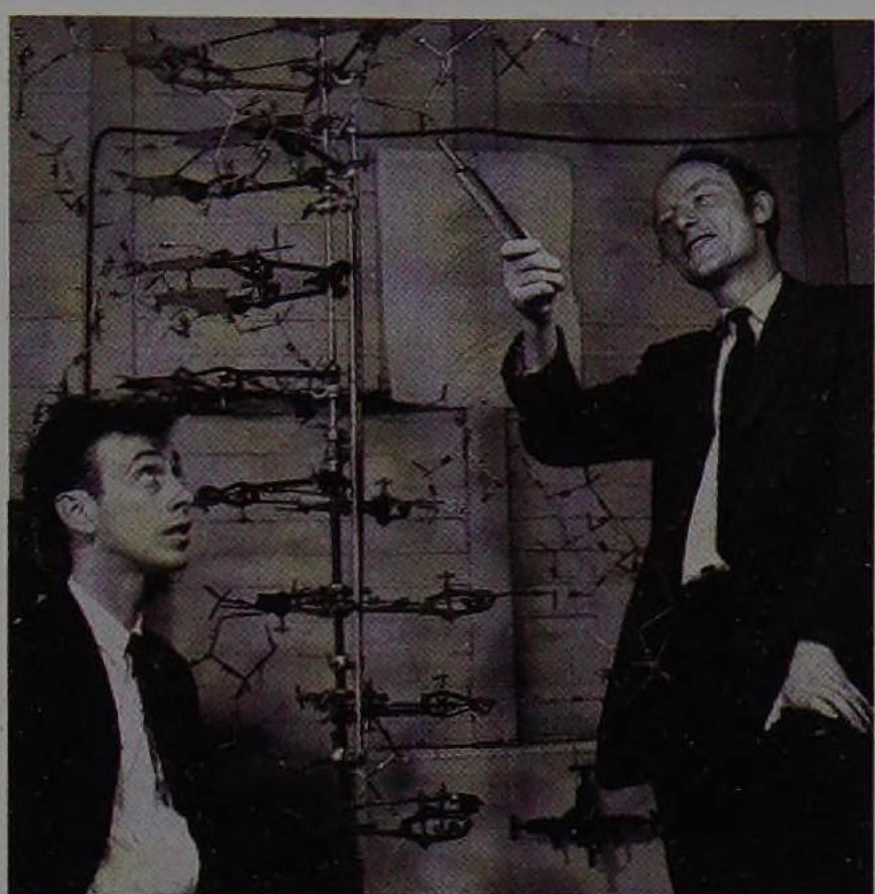
The fetus is fully grown, at about 36 cm (14 in) long. With fully formed lungs, it is ready to be born.

Mother and baby

Many mothers breast-feed their babies. Breast milk gives the baby the nutrients for growth and development in the early months before it can eat solid food. Milk is produced by glands inside the breasts and released when the baby suckles.

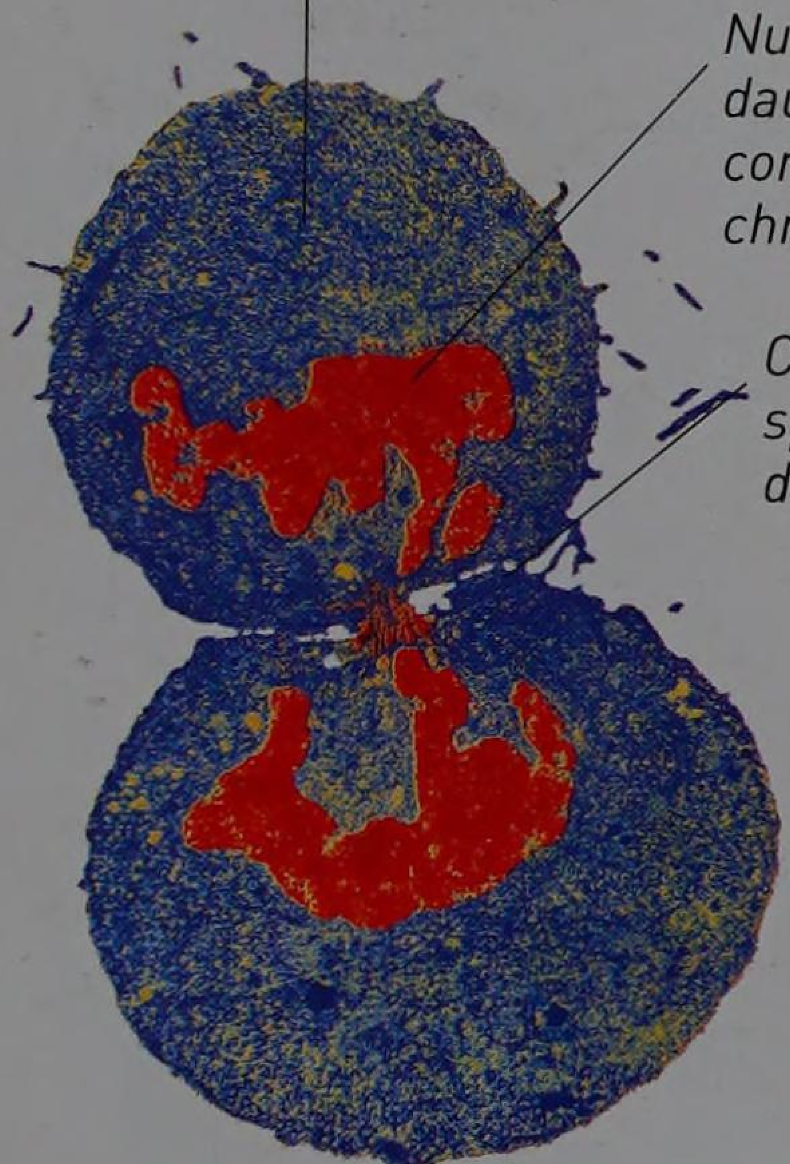
Growth and development

From birth to old age, we follow the same pattern of growth and body development. Physical and mental changes turn us from children into adults, and growth stops by our early 20s. The body then matures, and in later years begins to deteriorate. This pattern is controlled, like all of the body's processes, by 23 pairs of chromosomes in the nucleus of every body cell. Each chromosome is made up of deoxyribonucleic acid (DNA). Sections of DNA, called genes, contain the coded instructions that build and maintain the body.

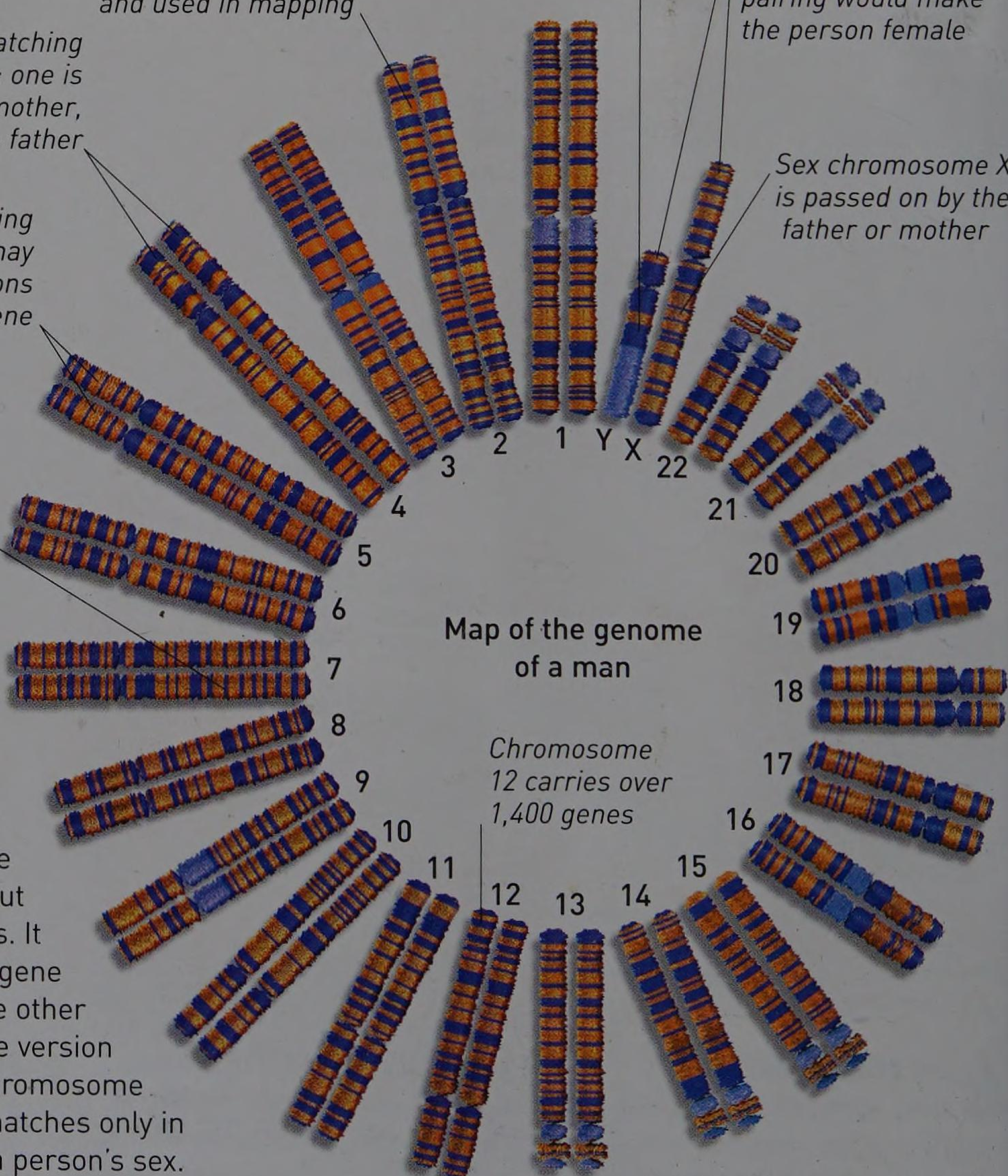


Master molecule
US biologist James Watson (1928–) and British biophysicist Francis Crick (1916–2004) showed that the DNA molecule has two strands that spiral like a twisted ladder. Its rungs hold the code forming the instructions in genes.

Genes and inheritance
If a man and woman reproduce, they each pass on a set of genes to their child. The genes that this girl inherited from her mother and father are mostly identical, but some are different, so her combination of genes is unique.



Cell division
Bodies grow by making new cells. Cells reproduce by dividing in two. For most cells, this involves mitosis. Each chromosome duplicates inside a parent cell to produce an identical copy. The copies move apart, and the cell divides to produce two daughter cells that are identical to each other.



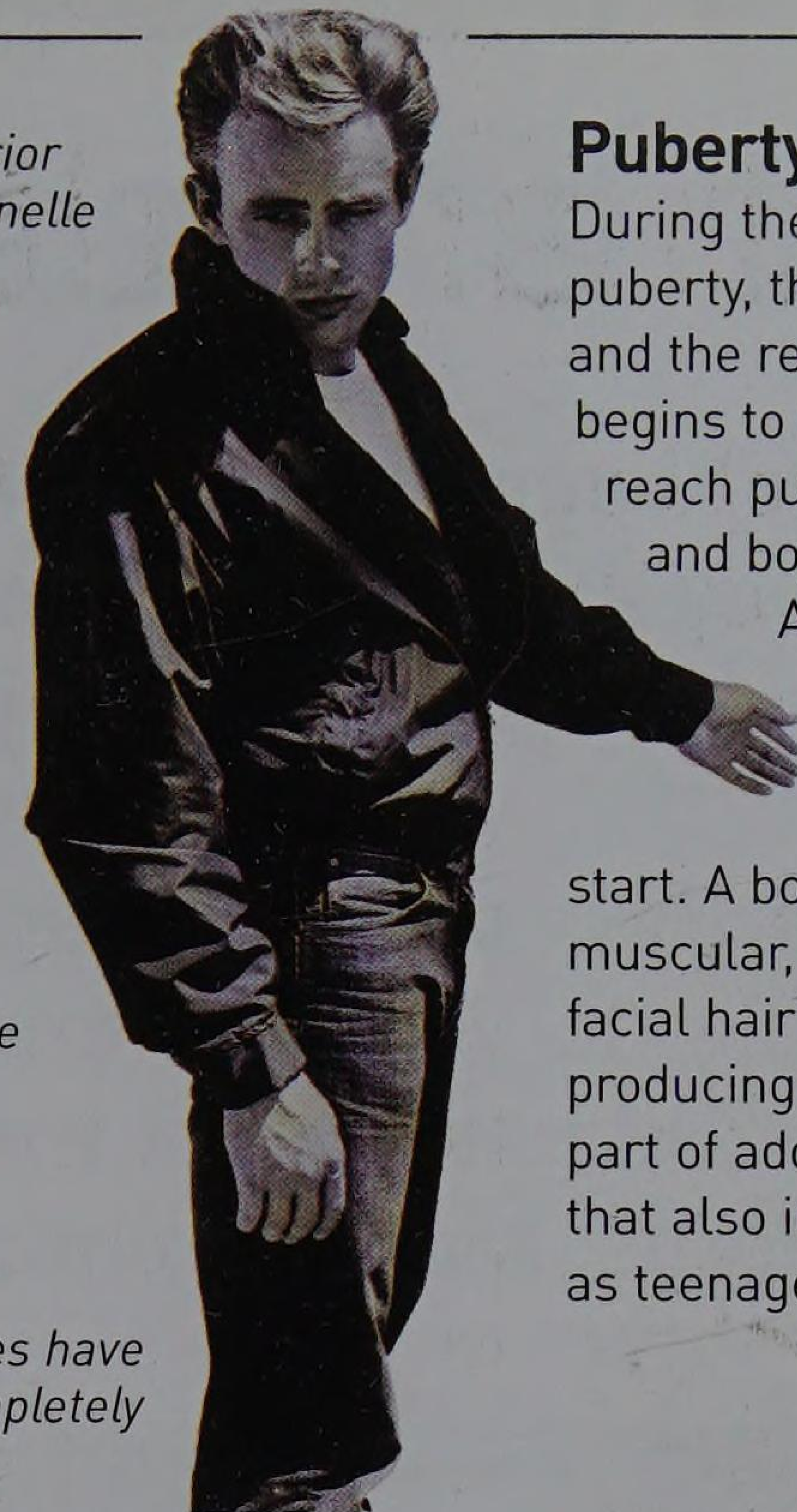
Human genome
Every human cell contains 23 chromosomes, called the genome. Each has a partner. One of each pair is from the mother, one is from the father.

Each chromosome has the same genes as its partner, but not always identical versions. It might carry the version of a gene giving blue eyes, but the other chromosome might have the version for brown. While 22 of the chromosome pairs match, the 23rd pair matches only in females and determines a person's sex.

Growth and the skeleton

Before birth, the skeleton is made up of either flexible cartilage or, in the skull, membranes reinforced with fibres. As the fetus grows, most of these tissues are ossified – replaced by hard bone. But the bones of the cranium (skull) are incomplete at birth, and are connected by fontanelles, or membranes that allow the brain to grow. By early childhood, these too are ossified, and the skull bones are knitted together. During childhood, the skull's facial bones grow rapidly to catch up with the cranium.

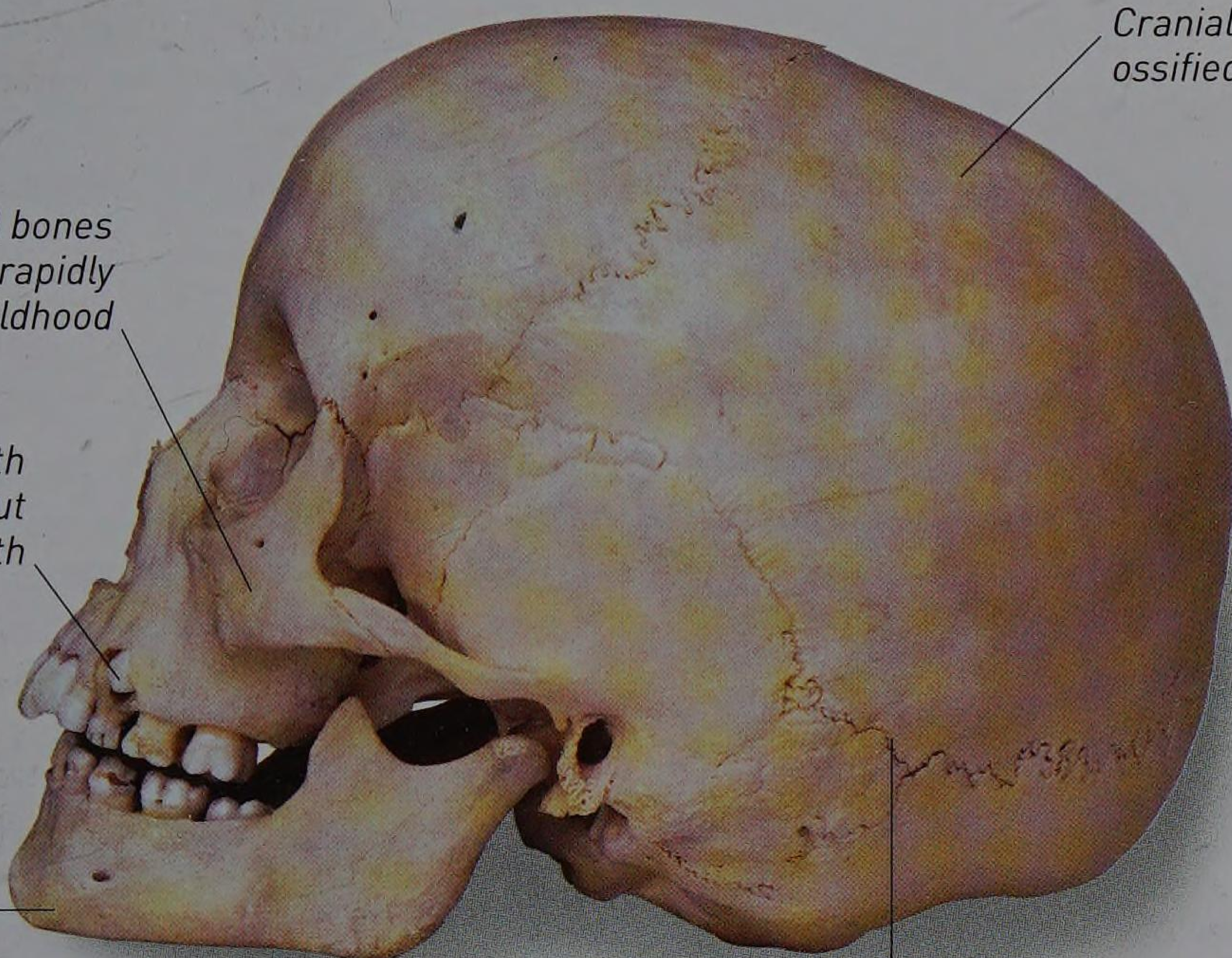
Fetal skull



Puberty and adolescence

During the three to four years of puberty, the body grows rapidly and the reproductive system begins to function. Most girls reach puberty at 10–12 years, and boys at 12–14 years.

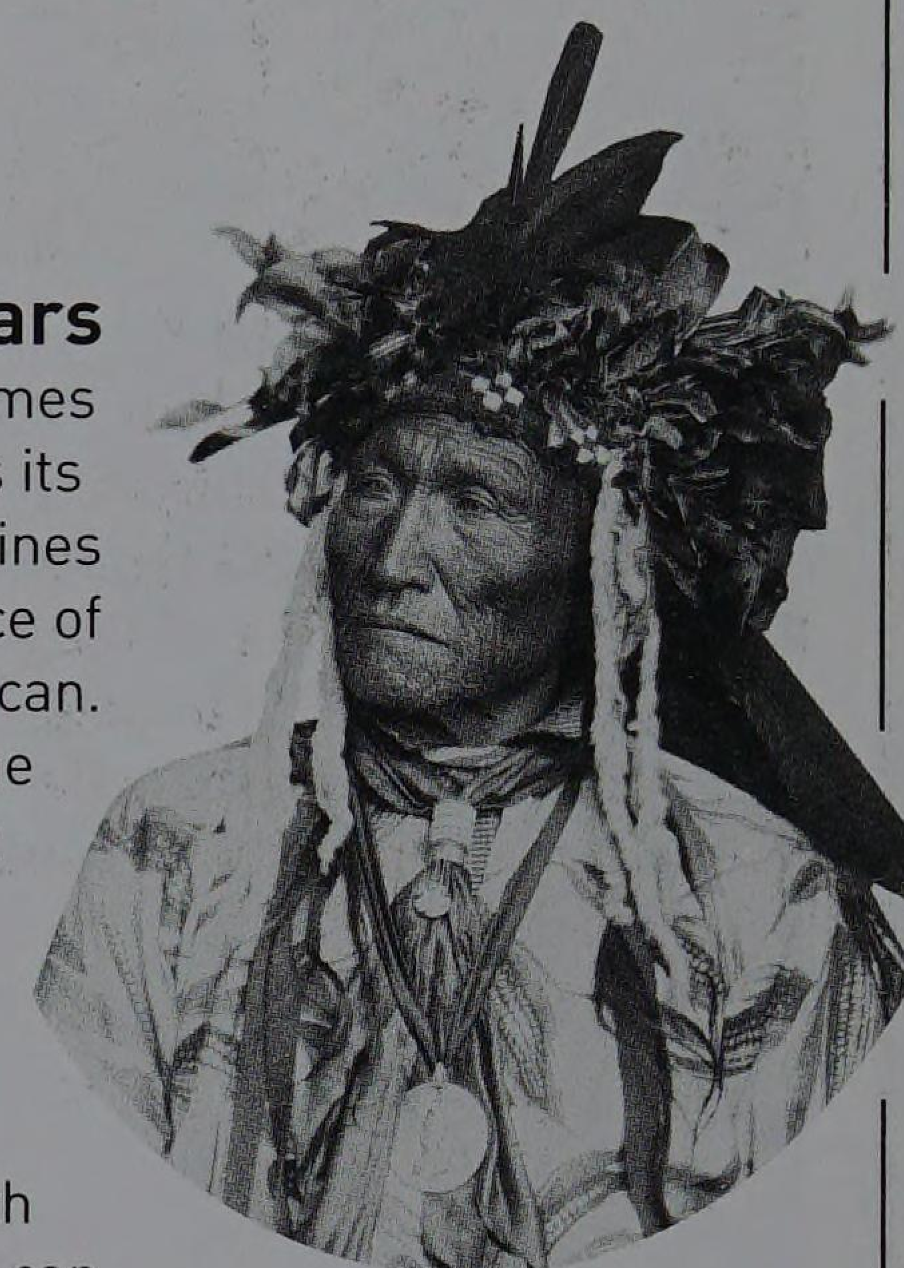
A girl's body becomes more rounded, she develops breasts, and her periods start. A boy's body becomes more muscular, his voice deepens, facial hair grows, and he starts producing sperm. Puberty forms part of adolescence, the process that also involves mental changes as teenagers turn into adults.



Six-year-old skull

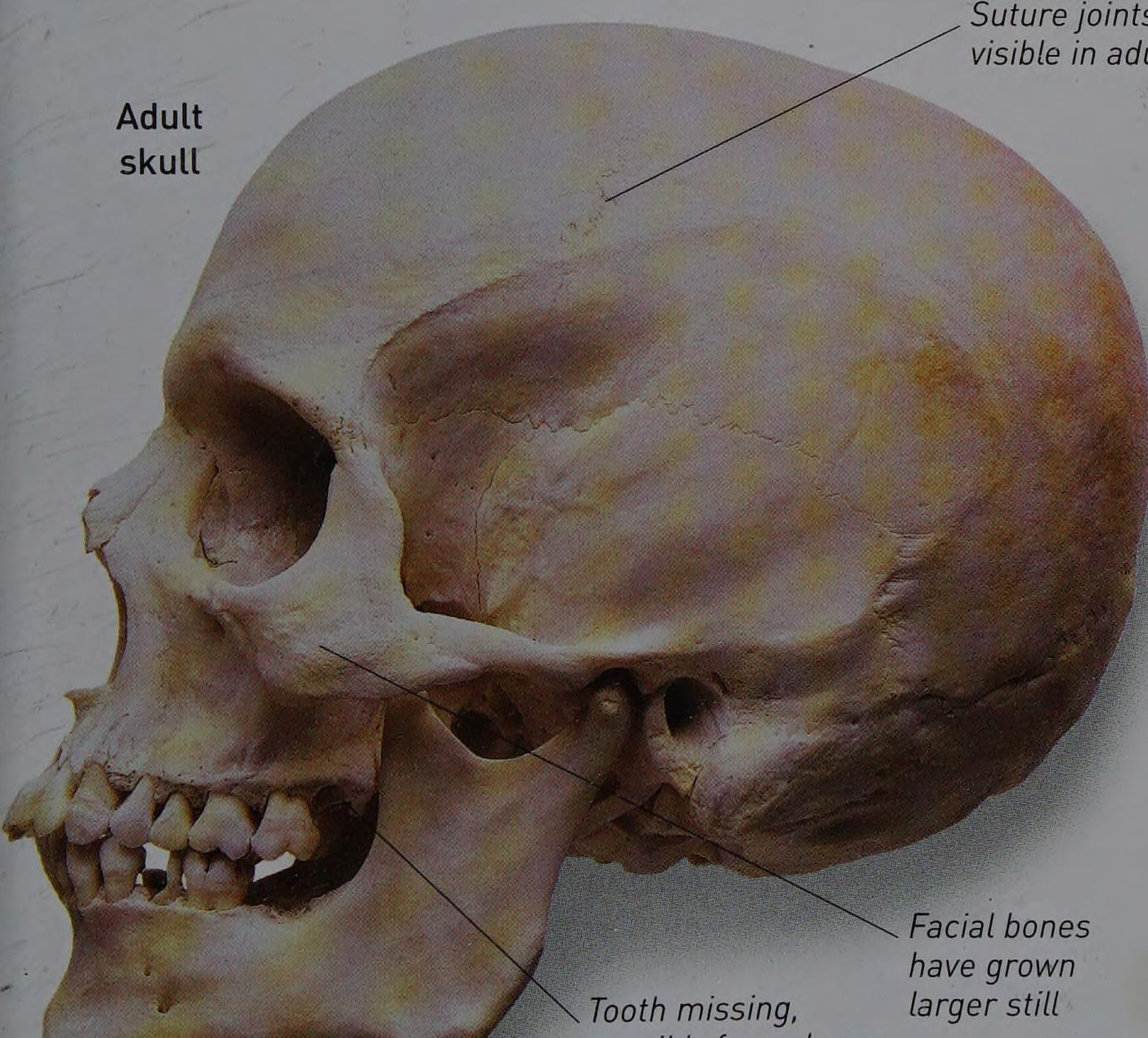
Later years

In our 50s, ageing becomes noticeable. The skin loses its springiness and develops lines and wrinkles, as in the face of this elderly Native American. The heart and lungs become less efficient, joints stiffen and bones become more fragile, vision is less effective, and brain function decreases. But looking after the body with healthy food and exercise can slow these changes and help us stay healthy well into our 80s.



Chief of the Crow tribe (c. 1906)

Adult skull



Life story from cradle to grave

Following birth and childhood, early adulthood is a time of responsibility and becoming a parent. Middle age brings wisdom, and the start of ageing. In old age, the body begins to decline until, eventually, we die. With better food, health care, and sanitation in the developed world, average life expectancy is almost 80 years, twice that of the 16th-century man above.

Future bodies

Advances in biology, medicine, and technology make it possible to repair or improve the human body in new ways, such as bionic limbs and artificial organs. For some people, research using stem cells or hybrid embryos interferes with the sanctity of life. Others predict a world of nanobots, cyborgs, and brain microchips.

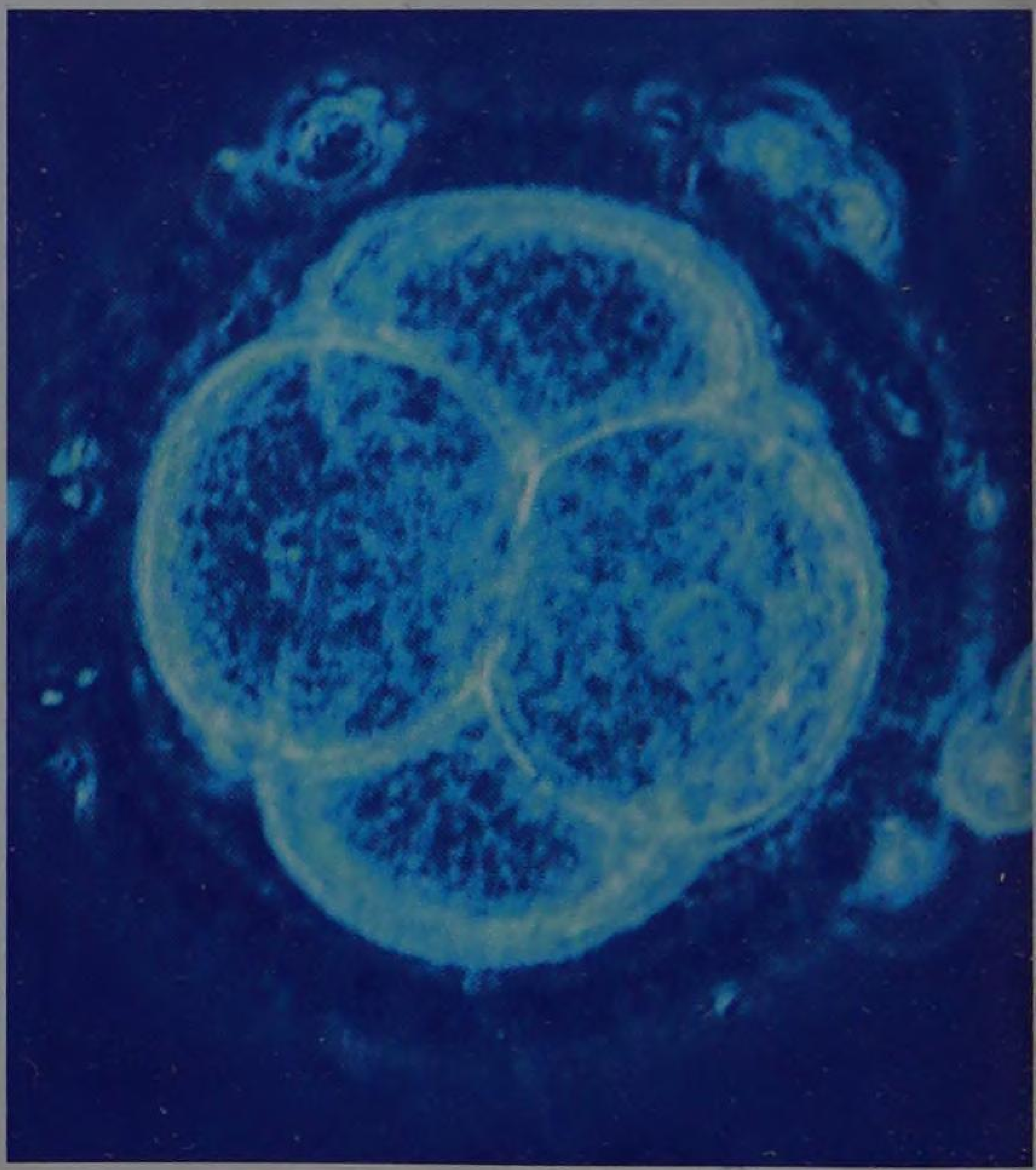
Stem cells taken from umbilical cord blood

Gene therapy

Each body cell contains over 20,000 genes, the DNA instructions that build and run it. A faulty gene can cause disease. Scientists hope it will soon be possible to cure some conditions using gene therapy – replacing faulty genes with normal ones carried into body cells by a harmless virus.

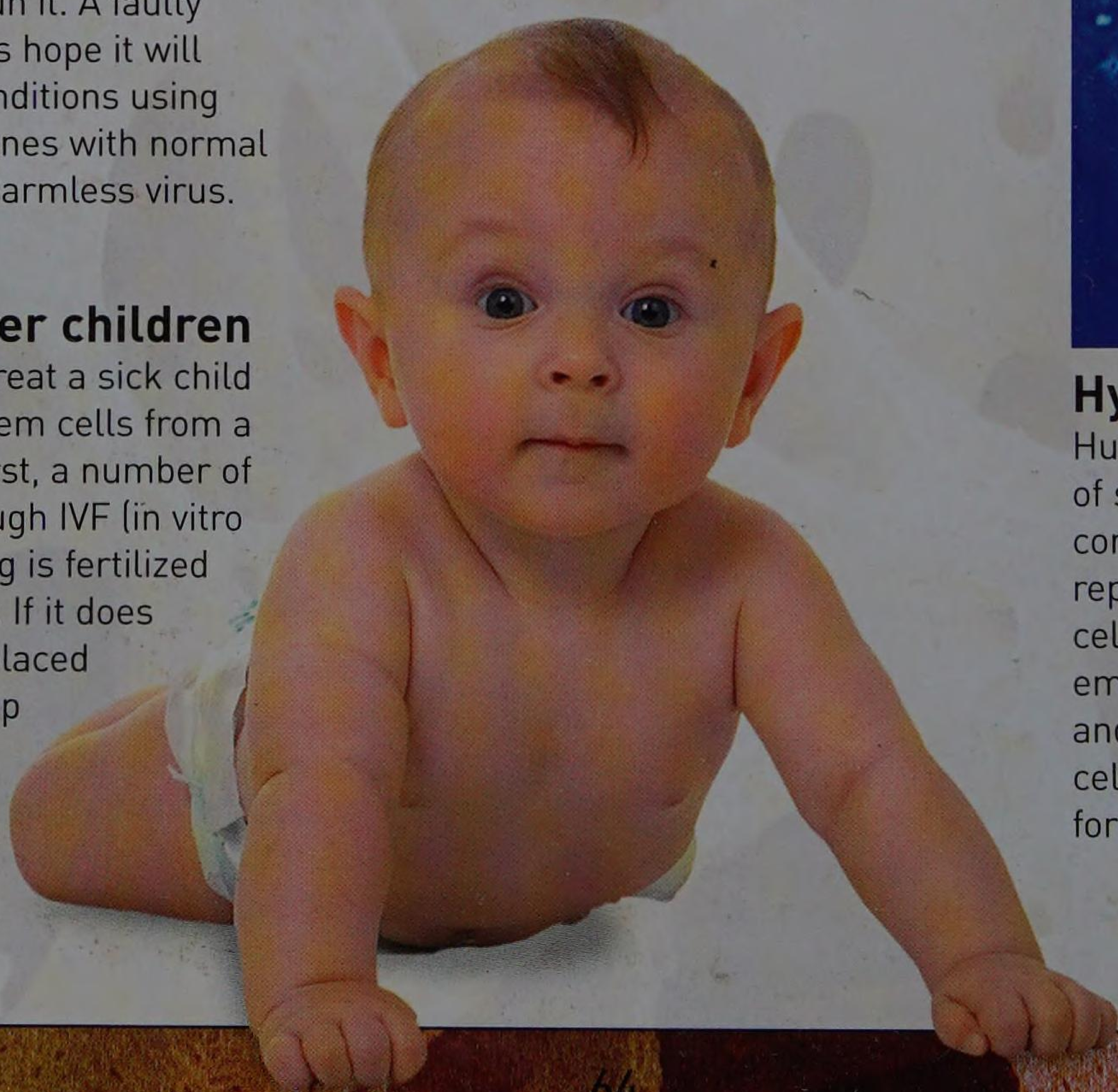
Stem cells

Doctors believe unspecialized cells, called stem cells, can be used to repair diseased or damaged tissues in patients. Stem cells divide to produce a range of cell types and so can build many types of body tissue.



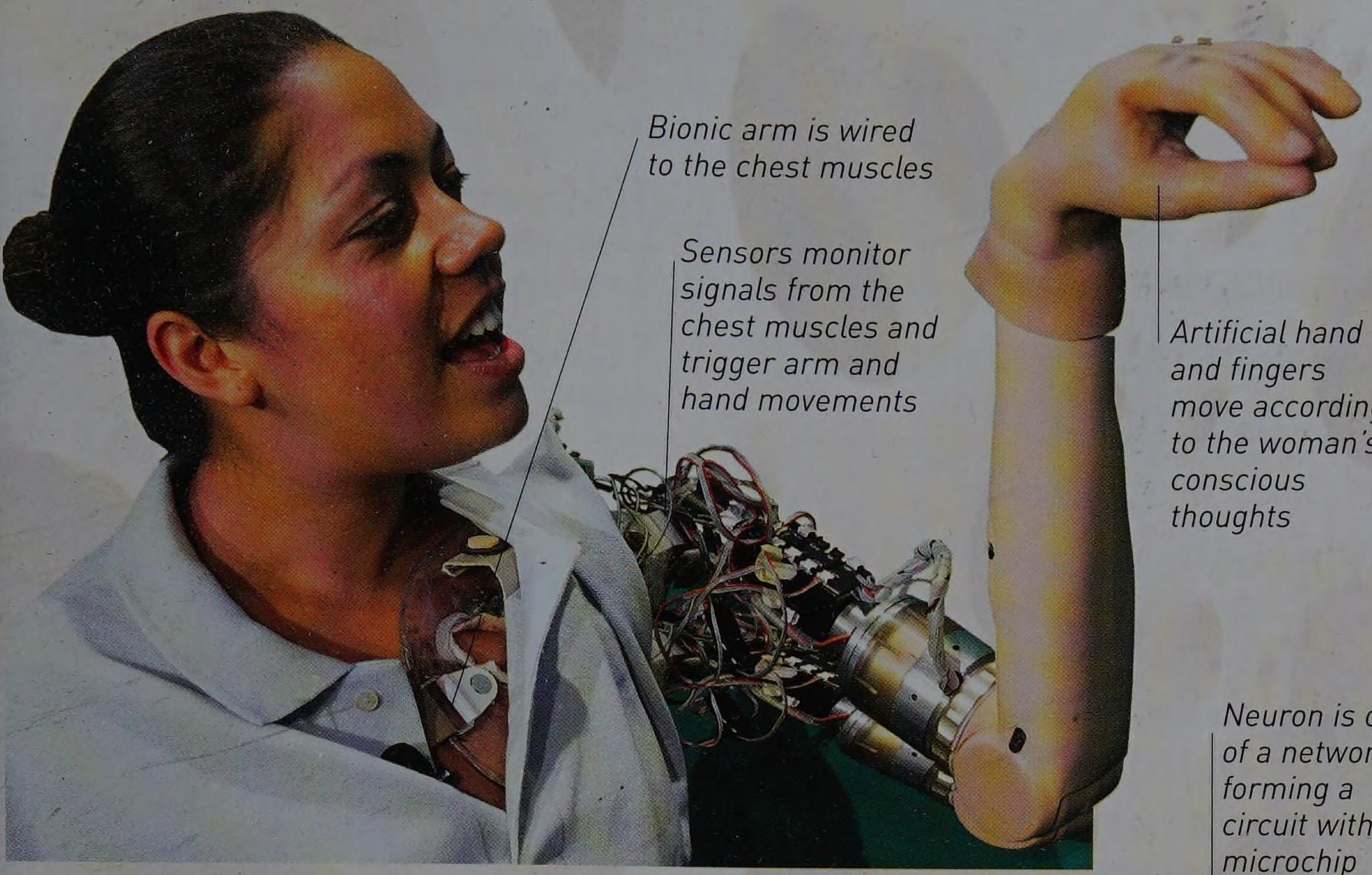
Hybrid embryos

Human embryos are a controversial source of stem cells. As an alternative, the DNA-containing nucleus in a cow's egg is replaced by a nucleus from a human skin cell. The cell divides to create a hybrid embryo that is 99.9 per cent human and is a new source of stem cells to research cures for diseases.



Designer children

One day it may be possible to treat a sick child with a faulty gene by using stem cells from a specially designed sibling. First, a number of embryos are created through IVF (in vitro fertilization), where an egg is fertilized outside the body in a laboratory. If it does not have the faulty gene, it is placed in the mother's uterus to develop into a baby. When the designer child is born, stem cells in its discarded umbilical cord are used to treat its sick sibling.

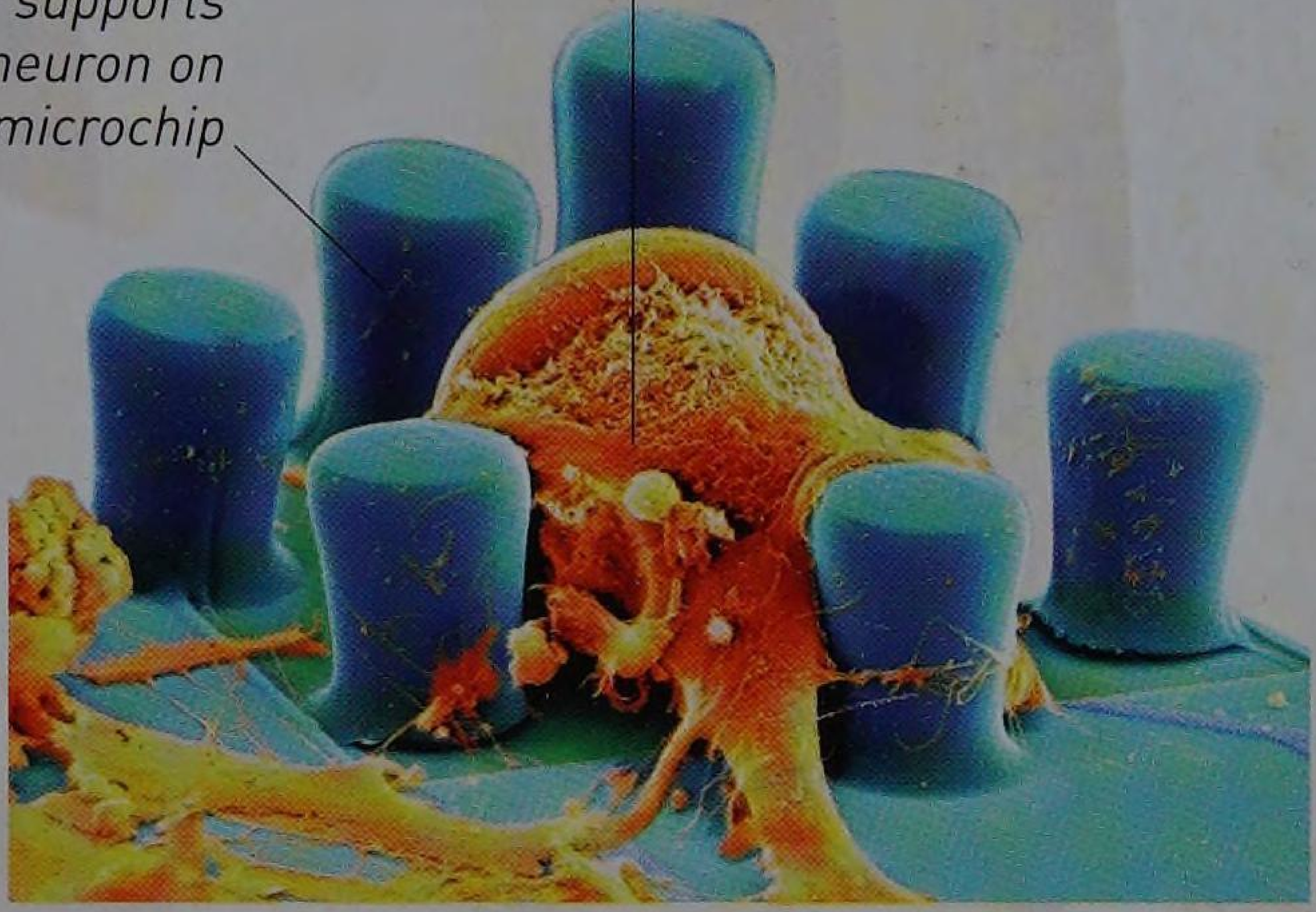


Bionic limbs

After this patient lost her arm in an accident, a bionic arm was wired to her chest muscles. When she thinks about moving her hand, messages travel to the muscles, which send out electrical signals. Sensors pass these to a tiny computer that tells her arm how to move.

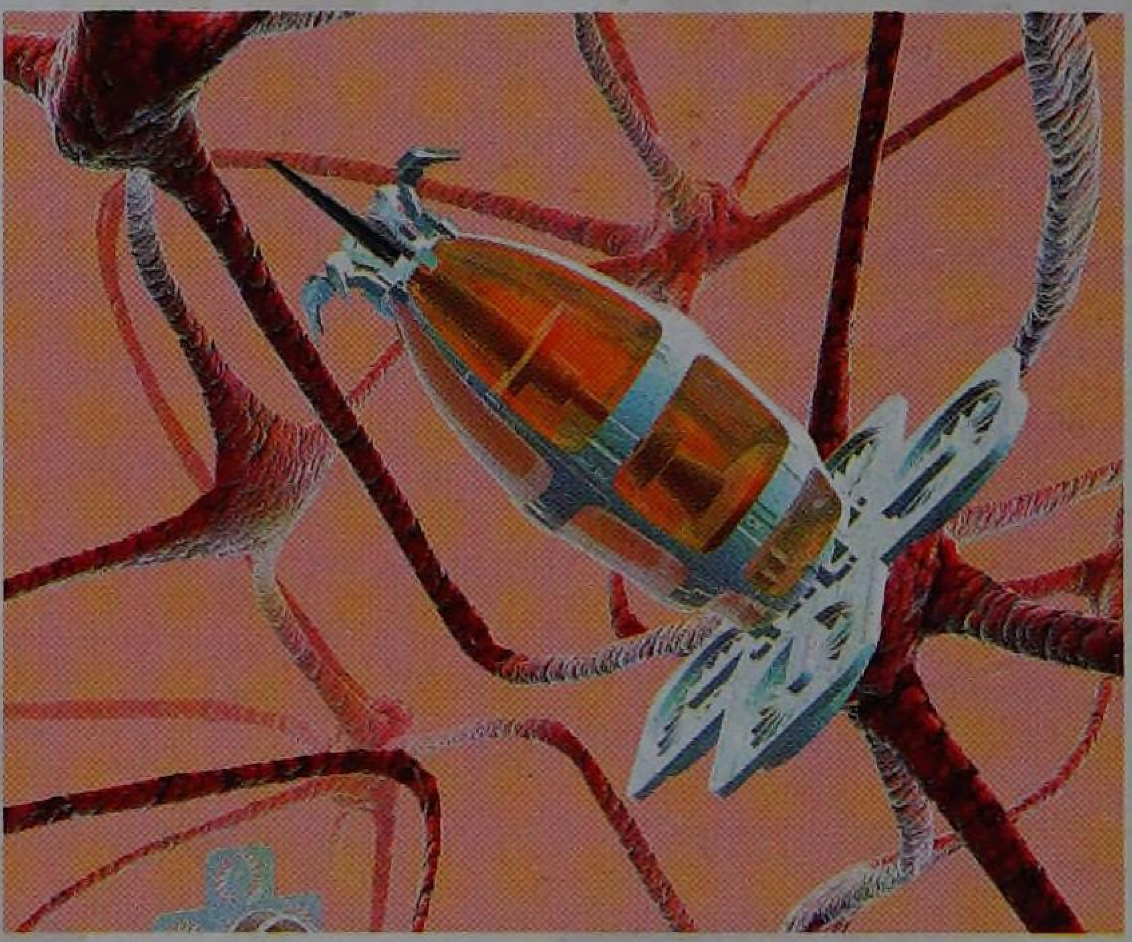
Growing organs

Currently, diseased organs are replaced by transplanting a donor organ from someone else. Using cells from the patient instead, bladder tissue has been grown around a mould (above) and the new bladder was successfully implanted into the patient.



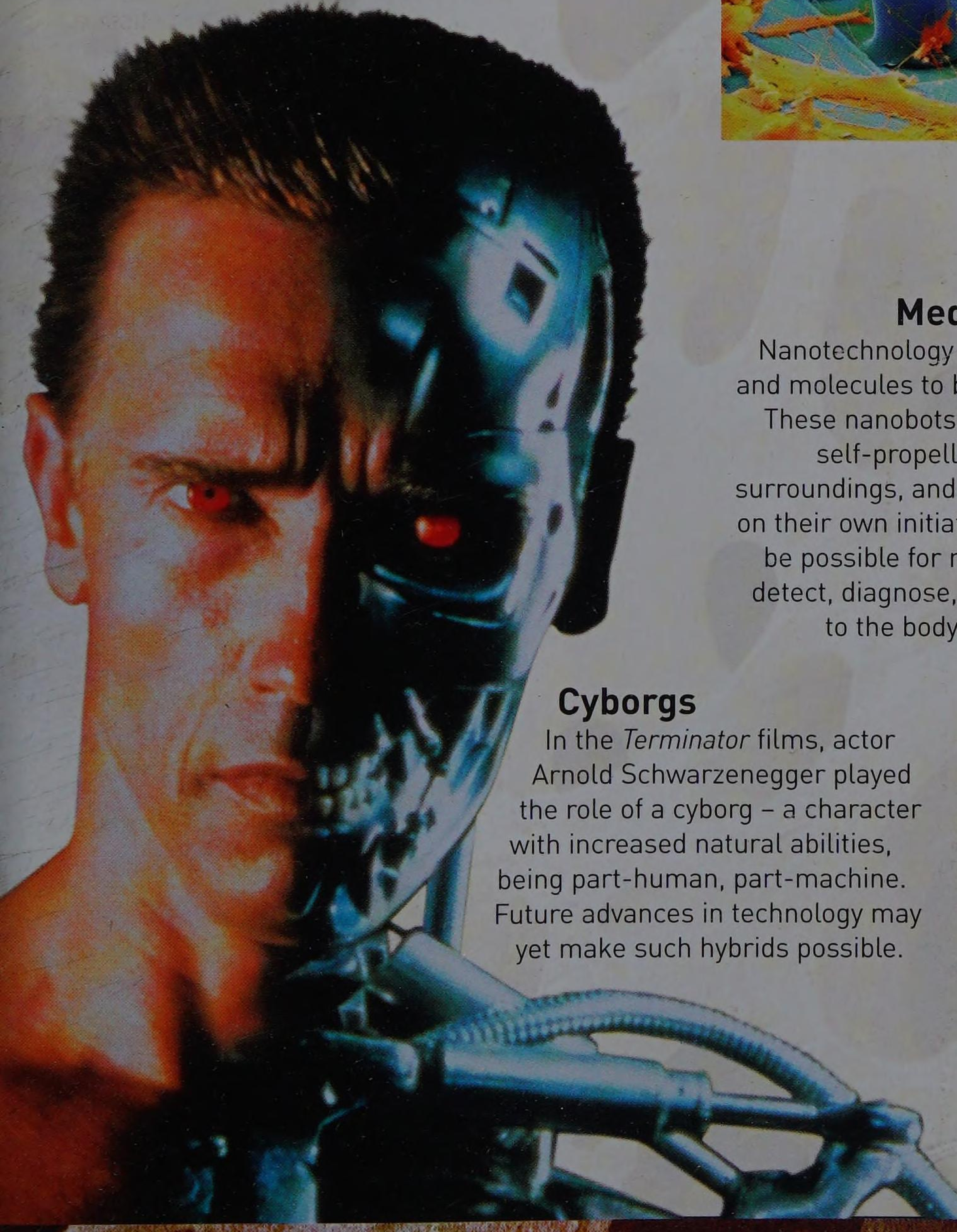
Brain microchips

This microchip forms a miniature electronic circuit with a network of neurons and can stimulate them to send and receive signals to one another and to the microchip. Future scientists might use neuron–microchip circuits to repair brain damage or boost memory or intelligence.



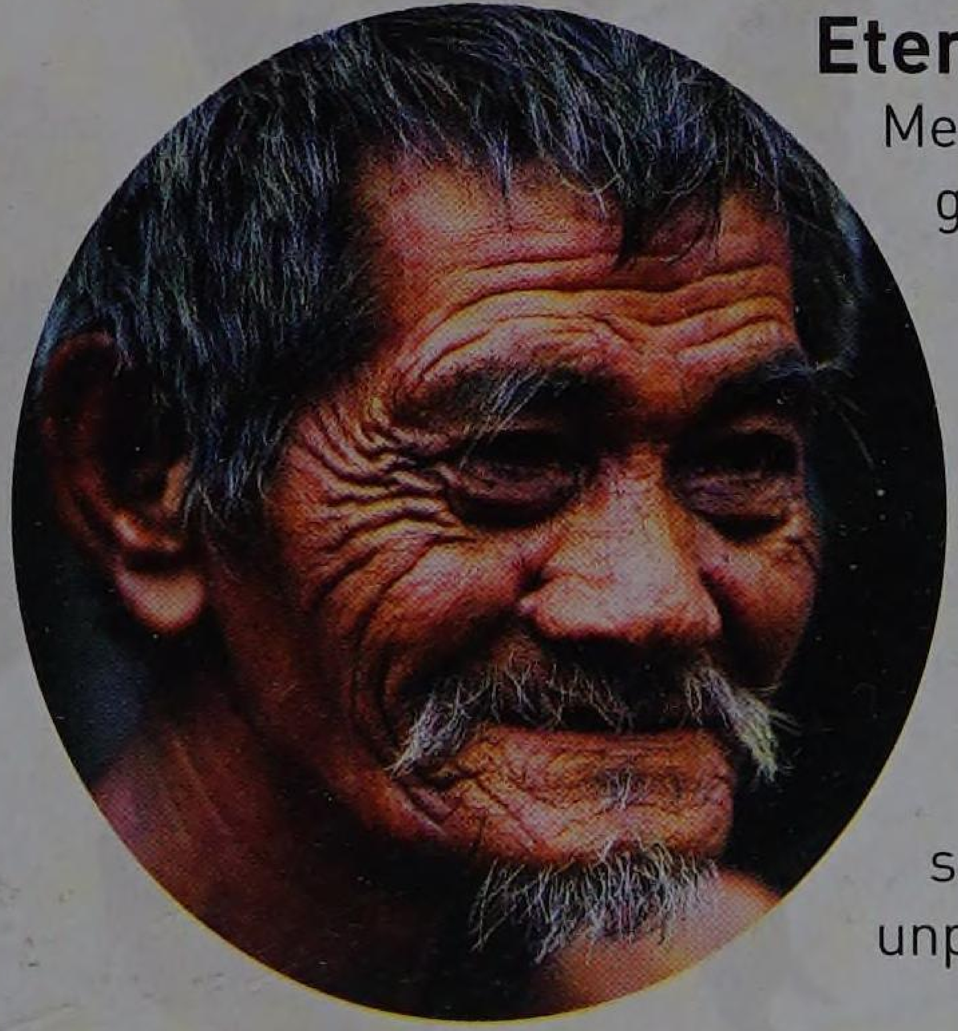
Medical nanobots

Nanotechnology manipulates atoms and molecules to build tiny machines. These nanobots, or nanorobots, are self-propelled, respond to their surroundings, and can carry out tasks on their own initiative. One day, it may be possible for medical nanobots to detect, diagnose, and repair damage to the body's cells and tissues.



Cyborgs

In the *Terminator* films, actor Arnold Schwarzenegger played the role of a cyborg – a character with increased natural abilities, being part-human, part-machine. Future advances in technology may yet make such hybrids possible.



Eternal life?

Medical advances, such as gene therapy and organ replacement, together with lifestyle changes, could enable everyone to live longer. But what quality of life would there be for a 150-year-old? And how would our crowded planet support so many extra, possibly unproductive, human beings?

Timeline

With each new discovery, scientists have built up a clearer picture of the body and its systems. Even so, there remain many mysteries about the workings of the human body.

Statue of Imhotep c. 2650 BCE

c. 160,000 BCE
Modern humans first appear.

c. 2650 BCE
Egyptian Imhotep is the earliest known physician.

c. 1500 BCE
The earliest known medical text, the *Ebers Papyrus*, is written in Egypt.

c. 500 BCE
Greek physician Alcmaeon suggests that brain, and not heart, is the seat of thought and feelings.

c. 420 BCE
Greek physician Hippocrates emphasizes the importance of diagnosis.

c. 280 BCE
Herophilus of Alexandria describes the cerebrum and cerebellum of brain.

c. 200 CE
Greek-born Roman doctor Claudius Galen describes, incorrectly, how human body works; his teachings are not challenged until the 1500s.

c. 1025
Persian doctor Avicenna publishes the *Canon of Medicine,* which will influence European medicine for the next 500 years.

c. 1280
Syrian doctor Ibn an-Nafis shows that blood circulates around the body.

c. 1316
Italian anatomist Mondino dei Liuzzi publishes his dissection guide *Anatomy*.

c. 1500
Italian artist and scientist Leonardo da Vinci makes anatomical drawings based on his own dissections.

Anatomical drawing by Leonardo da Vinci

1543
Flemish doctor Andreas Vesalius publishes *On the Structure of the Human Body*, which accurately describes human anatomy.

1562
Italian anatomist Bartolomeo Eustachio describes the ear in *The Examination of the Organ of Hearing*.

1590
Dutch spectacle maker, Zacharias Janssen, invents the microscope.

1603
Hieronymus Fabricius, an Italian anatomist, describes the structure of a vein in his book, *On the Valves of Veins.*

1628
English doctor William Harvey describes blood circulation in *On the Movement of the Heart and Blood in Animals*.

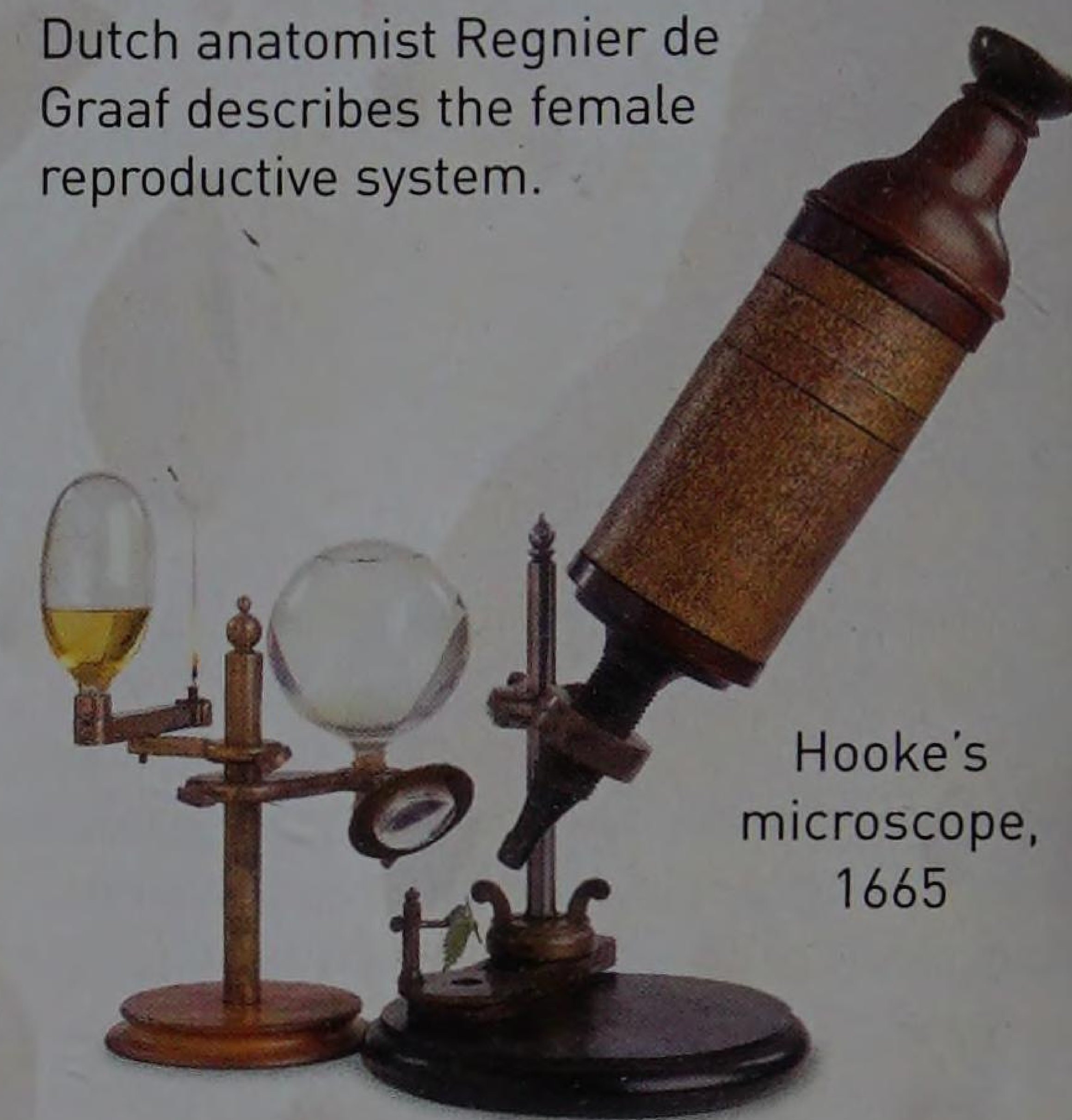
1662
French philosopher René Descartes' book, *Treatise of Man*, describes the human body as a machine.

1663
Italian biologist Marcello Malpighi discovers capillaries, the small blood vessels that link arteries and veins.

1664
English doctor Thomas Willis describes the blood supply to the brain.

1665
English physicist Robert Hooke coins the term "cell" for the smallest units of life he sees through his compound microscope.

1672
Dutch anatomist Regnier de Graaf describes the female reproductive system.



Hooke's microscope, 1665

1674–77
Antoni van Leeuwenhoek, a Dutch cloth merchant and microscopist, describes human blood cells and sperm cells.

1691
English doctor Clopton Havers describes the microscopic structure of bones.

1775
French chemist Antoine Lavoisier discovers oxygen and later shows that cell respiration consumes oxygen.

1800
French doctor Marie-François Bichat shows that organs are made of groups of cells called tissues.

1811
Scottish anatomist Charles Bell shows that nerves are bundles of nerve cells.

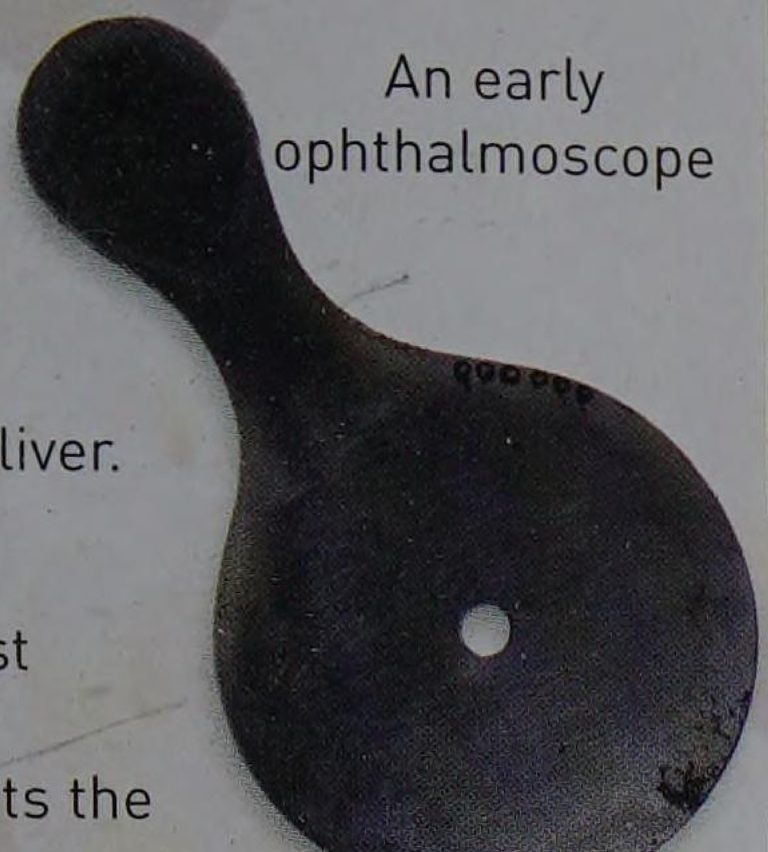
1816
French doctor René Laënnec invents the stethoscope to listen to the lungs and heart.

1833
American army surgeon William Beaumont publishes the results of his experiments into the mechanism of digestion.

1837
Czech biologist Johannes Purkinje observes neurons in the brain's cerebellum.

1842
British surgeon William Bowman describes the microscopic structure and workings of the kidney.

1848
French scientist Claude Bernard describes the workings of the liver.



An early ophthalmoscope

1851
German physicist Hermann von Helmholtz invents the ophthalmoscope, an instrument for looking inside the eye.

1861
French doctor Paul Pierre Broca identifies the area on the brain that controls speech.

1871
German scientist Wilhelm Kühne coins the term "enzyme" for substances that speed up chemical reactions inside living things.

1895
German physicist Wilhelm Roentgen discovers X-rays.

1901
Karl Landsteiner, an Austrian-American doctor, identifies blood groups, paving the way for more successful blood transfusions.

1905
British scientist Ernest Starling coins the term "hormone".

1930
American physiologist Walter Cannon coins the term "homeostasis"for mechanisms that maintain a stable state inside the body.

1933
German electrical engineer Ernst Ruska invents the electron microscope.

1952
US surgeon Joseph E Murray performs the first kidney transplant, on identical twins.

1952
In the US, Paul Zoll invents the pacemaker to control an irregular heartbeat.

1953
US biologist James Watson and British physicist Francis Crick discover the double-helix structure of DNA.

1958
British doctor Ian Donald uses ultrasound scanning to check the health of a fetus.

1961
US scientist Marshall Nirenberg cracks the genetic code of DNA.

1967
Magnetic resonance imaging (MRI) is first used to see soft tissues inside the body.

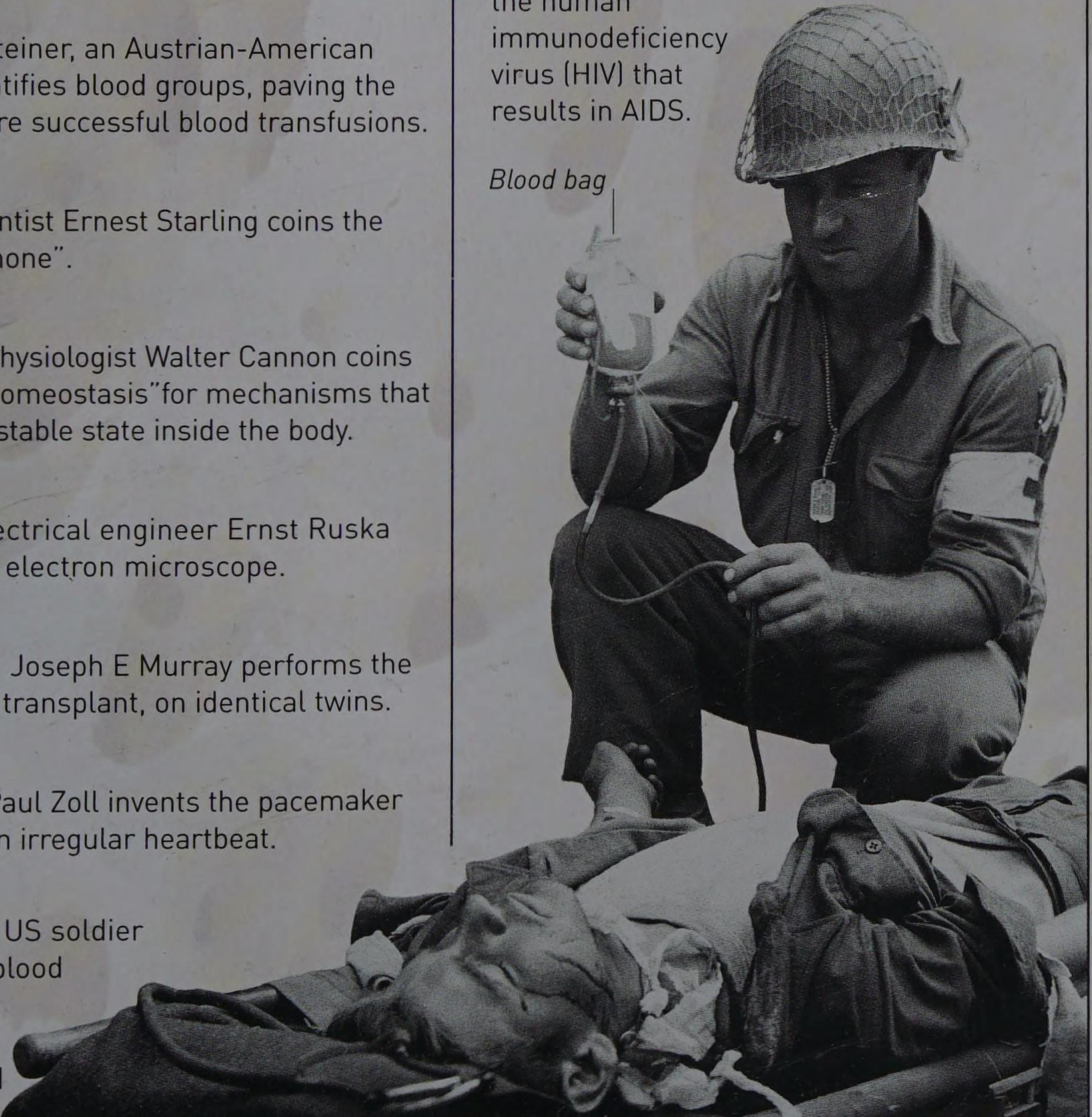
1972
Computed tomography (CT) scanning first produces images of human organs.

1980
Doctors perform "keyhole" surgery inside the body through small incisions with the assistance of an endoscope.

1980s
Positron emission tomography (PET) scans first produce images of brain activity.

1982
The first artificial heart, invented by US scientist Robert Jarvik, is transplanted into a patient.

1984
French scientist Luc Montagnier discovers the human immunodeficiency virus (HIV) that results in AIDS.

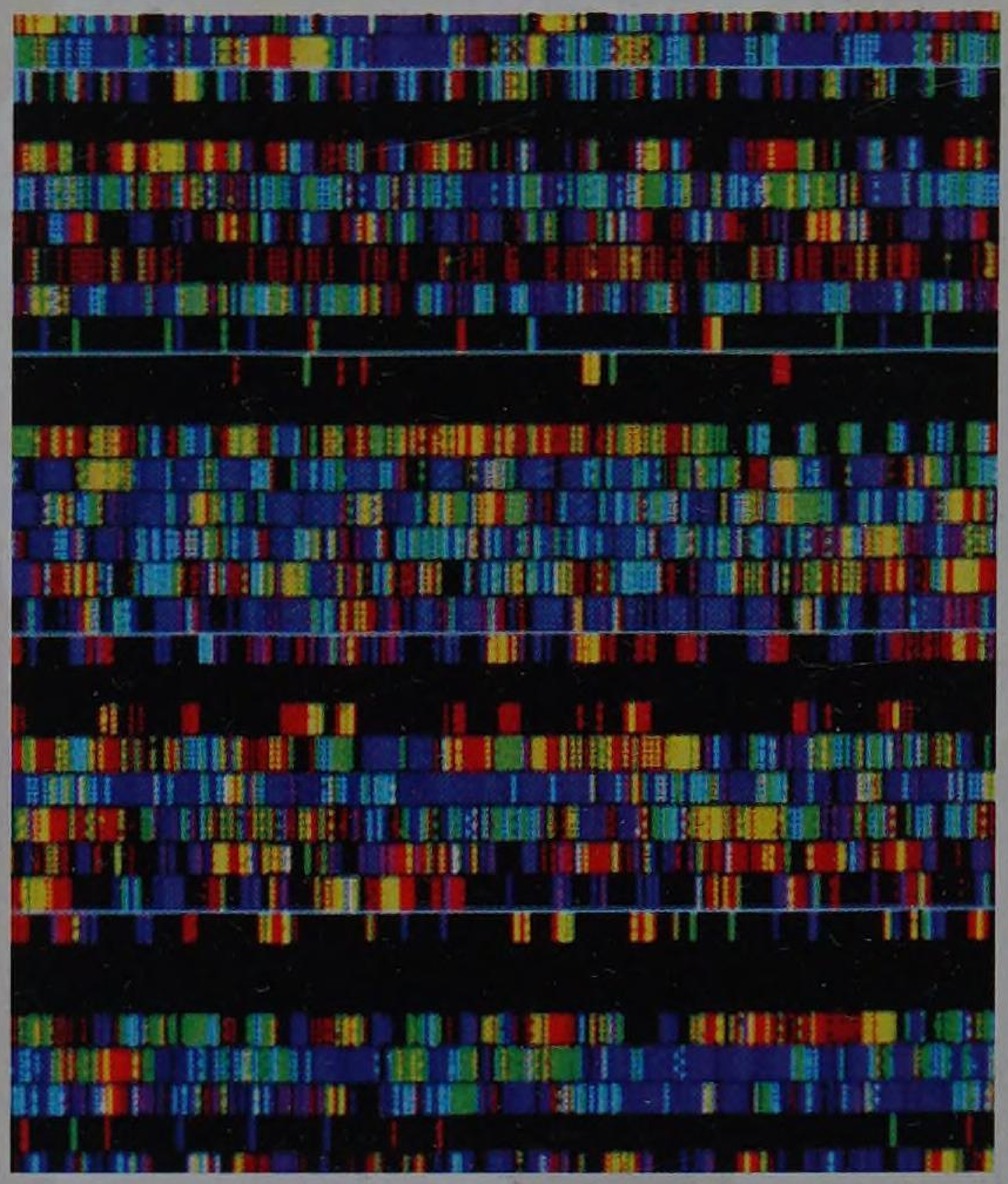


Blood bag

A wounded US soldier receives a blood transfusion during World War II

2001
Scientists perform the first germline gene transfer in animals, to prevent faulty genes being passed on to offspring.

2002
Gene therapy is used to treat an inherited immuno-deficiency disease that leaves the body unable to fight against infection.



Computer display of DNA sequencing

2003
Scientists publish results of the Human Genome Project, identifying the DNA sequence of a full set of chromosomes.

2006
A urinary bladder, grown in the laboratory from a patient's own cells, is successfully transplanted to replace a damaged organ.

2007
Thought to be useless, the appendix is shown to hold a back-up reservoir of bacteria that is essential to the workings of the large intestine.

2008
Dutch geneticist Marjolein Kreik becomes the first woman to have her genome sequenced.

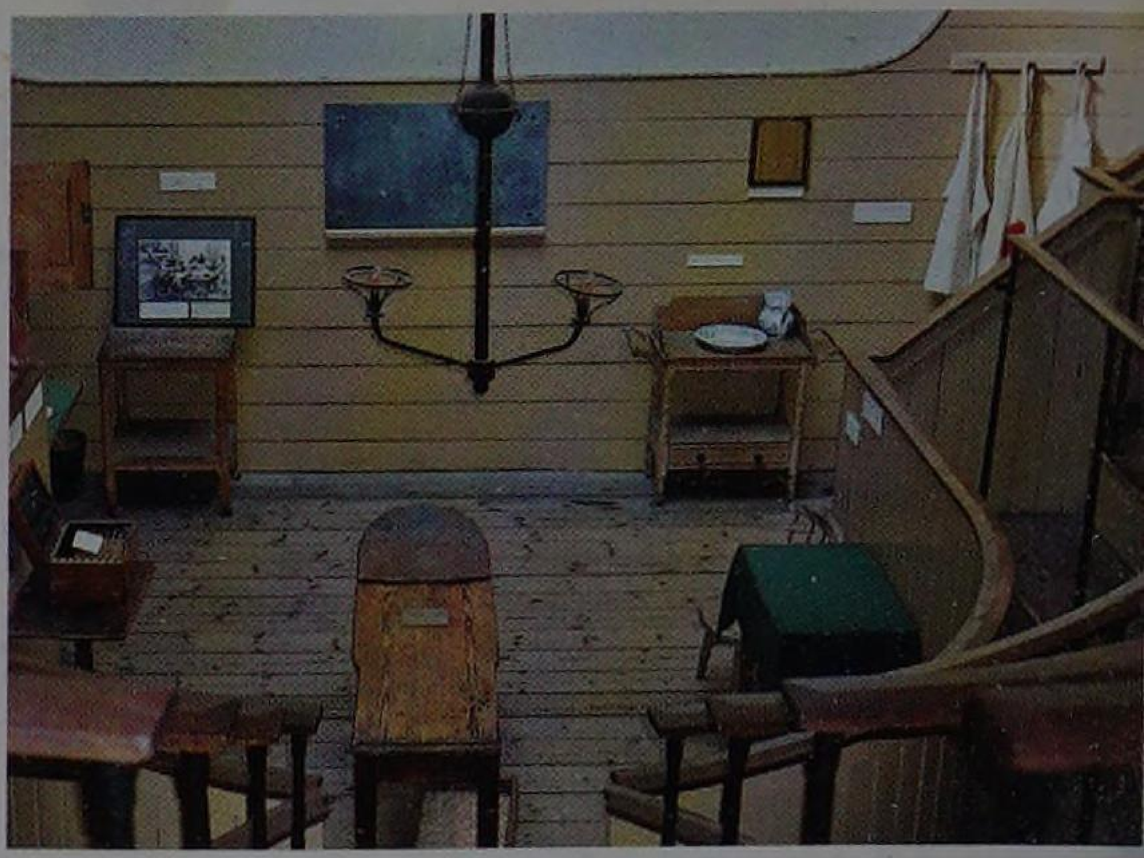
2010
DaVinci, a surgical robot, performs the world's first all-robotic surgery in Montreal, Canada.

Surgical robot, DaVinci

2013
Scientists in Japan create a functional human liver from skin and blood stem cells.

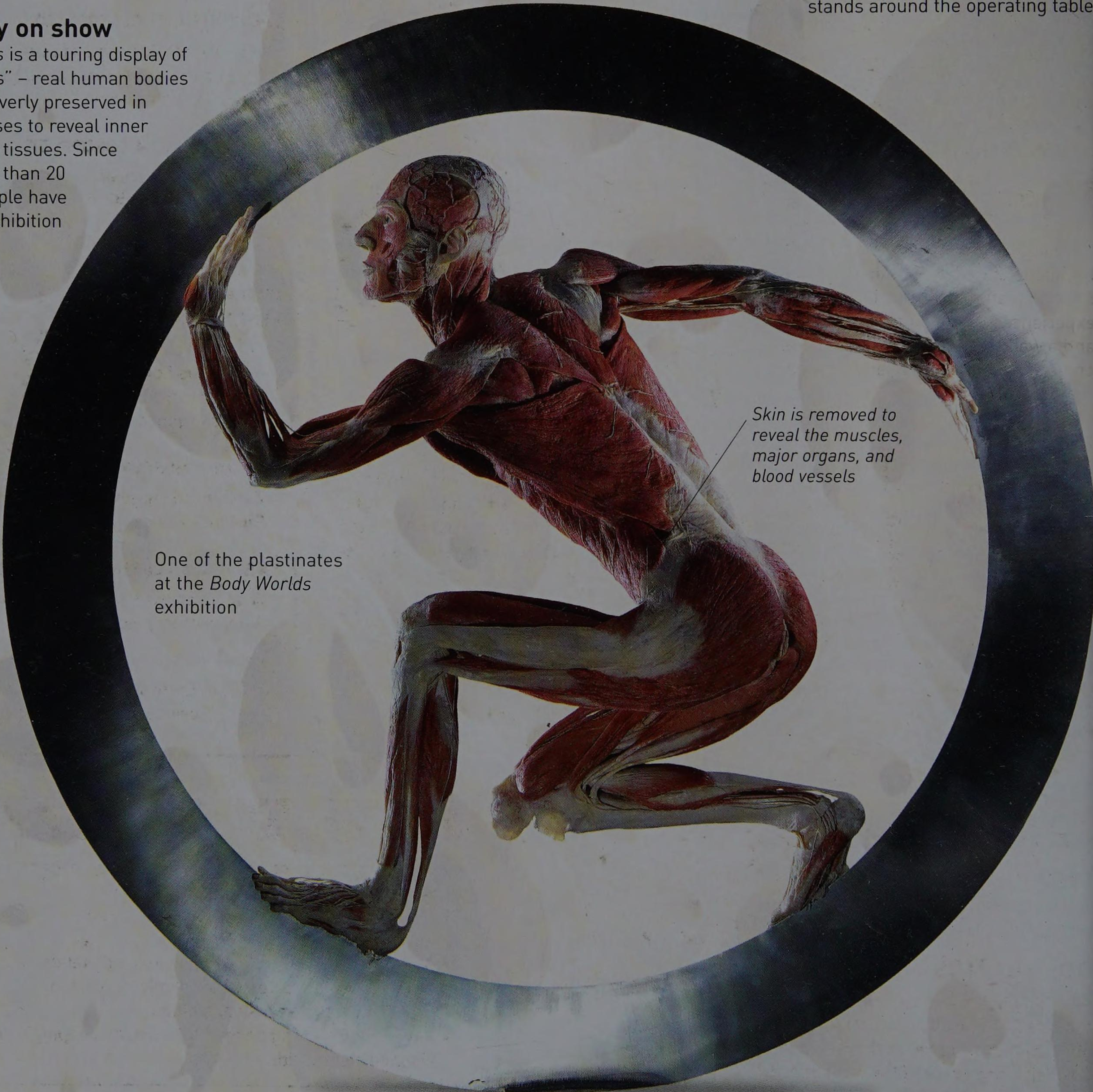
Find out more

Listen out for news stories about the latest discoveries in medical science, and documentaries about the human body and how it works. Look out for special exhibitions at museums near you, or search in your local library and online. You also have your own body to study! Take good care of it by eating healthily and exercising regularly.



The old operating theatre
This 19th-century operating theatre at the old site of St Thomas' hospital in London predates anaesthetics. Surgeons worked quickly to minimize a patient's suffering during amputations and other operations. Medical students watched from tiered stands around the operating table.

Anatomy on show
Body Worlds is a touring display of "plastinates" – real human bodies that are cleverly preserved in exciting poses to reveal inner organs and tissues. Since 1995, more than 20 million people have seen the exhibition worldwide.



Skin is removed to reveal the muscles, major organs, and blood vessels

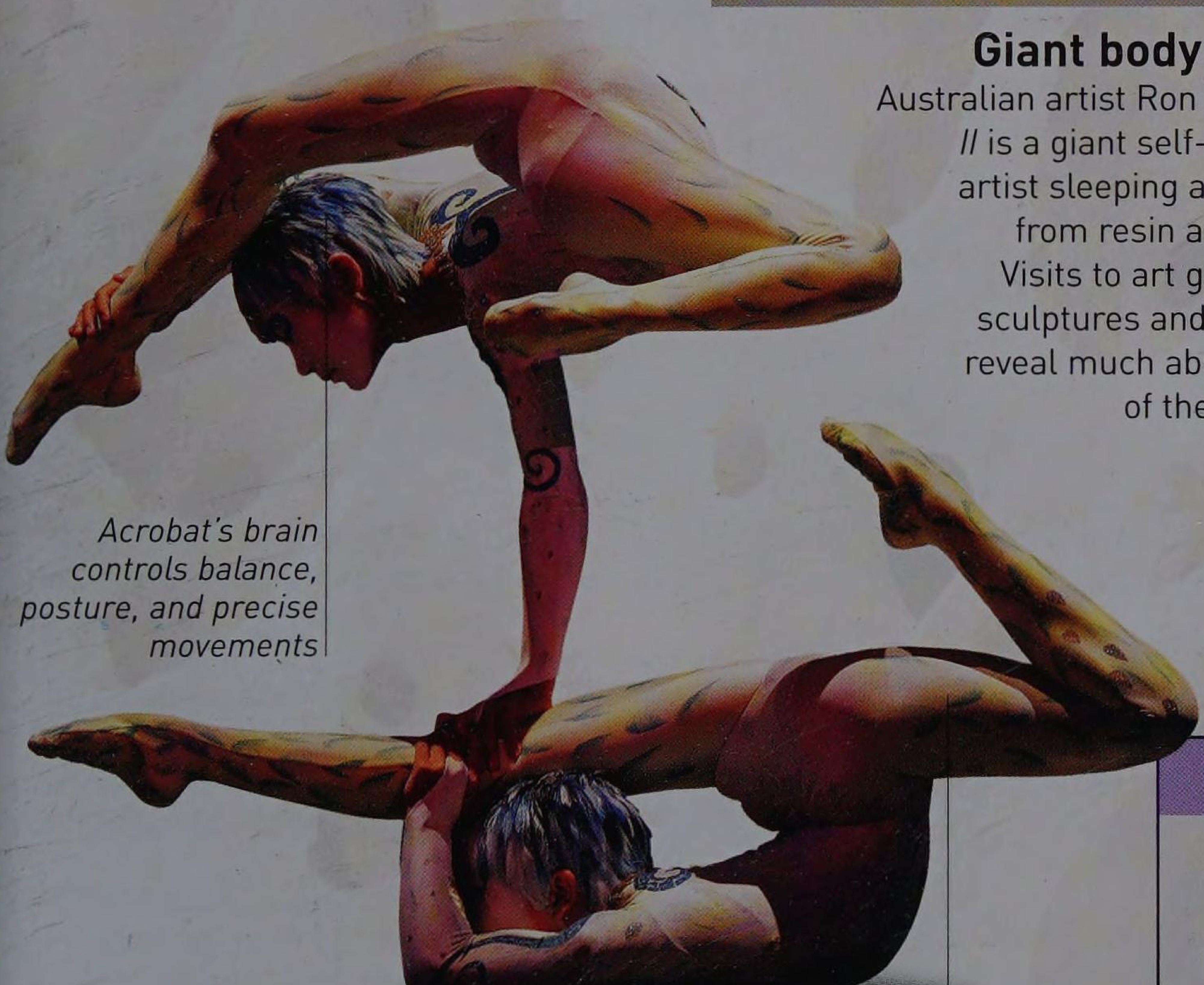
One of the plastinates at the *Body Worlds* exhibition

Walk-in body

At the Health Museum in Houston, Texas, USA, visitors can take a larger-than-life tour through the human body – including this arch created by a giant backbone and ribs. The Amazing Body Pavilion features exciting interactive experiences including a giant eyeball and a walk-through brain, and hands-on exhibits about health and well-being.

Giant body sculpture

Australian artist Ron Mueck's *Mask II* is a giant self-portrait of the artist sleeping and is sculpted from resin and fibre glass. Visits to art galleries to see sculptures and paintings can reveal much about the variety of the human form.



Acrobat's brain controls balance, posture, and precise movements

Muscle and joint flexibility is achieved by constant training

ACROBATICS

Watching ballet and circus shows like the *Cirque du Soleil* provides a great opportunity to marvel at the strength, flexibility, and grace of the human body.

PLACES TO VISIT

CITÉ DES SCIENCES, PARIS, FRANCE
- Interactive displays of the human body
- Detailed explorations of DNA discoveries

FRANKLIN INSTITUTE, PHILADELPHIA, USA
- Giant walk-through heart
- *Melting humans* exhibit showing internal organs and systems

HALL OF SCIENCE, NEW YORK, USA
- Infrared camera maps your body's hot spots
- Lots of hands-on exhibits to explore perceptions, molecules, and health

THE HUNTERIAN, GLASGOW, UK
- Life-size plaster casts of dissections
- Anatomical specimens preserved in jars
- Scientific instruments

SCIENCE MUSEUM, LONDON, UK
- *Who am I?* gallery on genetics and identity
- Exhibits on the history of medicine

DUNDEE SCIENCE CENTRE, DUNDEE, UK
- Lots on the senses
- Interactive keyhole surgery exhibit
- Face-morphing

THACKRAY MUSEUM, UK
- Exhibits on surgery and Sherlock Bones

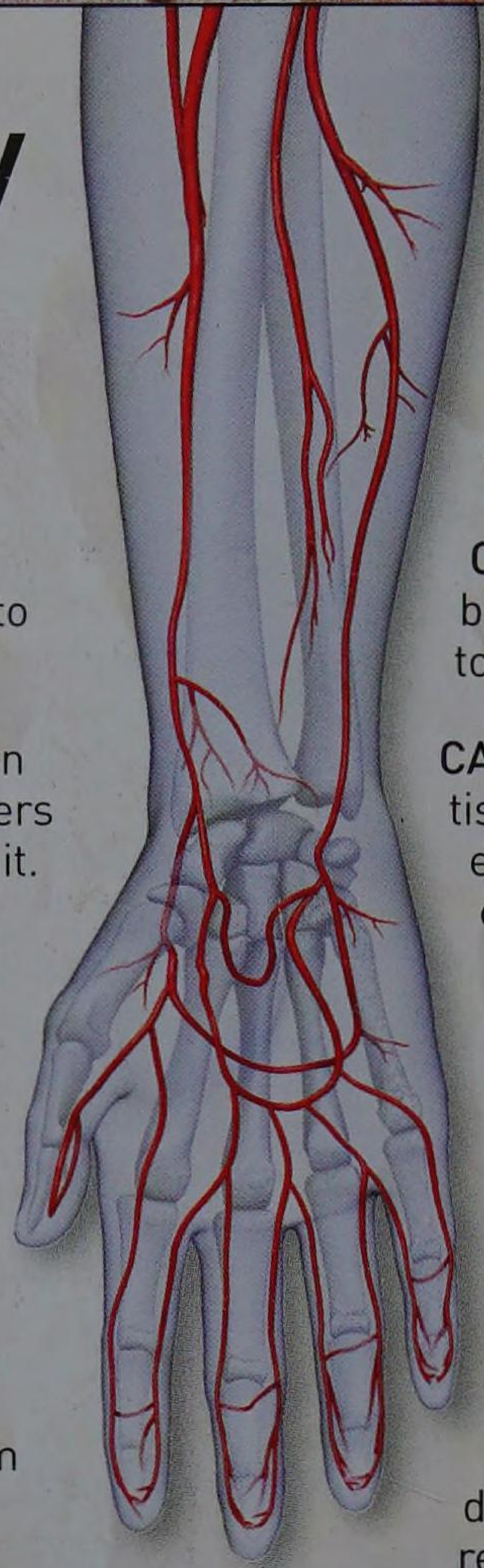
LA SPECOLA, FLORENCE, ITALY
- Anatomical wax models of 18th-century dissected bodies

Early stethoscope at the Science Museum, London

USEFUL WEBSITES

- A great website from the BBC covering all aspects of the body: **www.bbc.co.uk/science/humanbody**
- A fun, animated guide to the human body: **www.brainpop.com/health**
- A comprehensive guide to blood, from platelets to plasma – this website has several other body topics, too: **health.howstuffworks.com/blood**
- A website for young people, with tips on keeping healthy: **kidshealth.org/kids**

Glossary



Blood vessels supplying the lower arm and hand

ABDOMEN The lower part of the torso between the chest and hips.

ADOLESCENCE The period of physical and mental changes that occur during the teenage years and mark the transition from childhood to adulthood.

ALVEOLI The microscopic air bags in the lungs through which oxygen enters the blood and carbon dioxide leaves it.

AMNIOTIC FLUID A liquid that surrounds the fetus inside its mother's uterus. It protects the fetus from knocks and jolts.

ANATOMY The study of the structure of the human body.

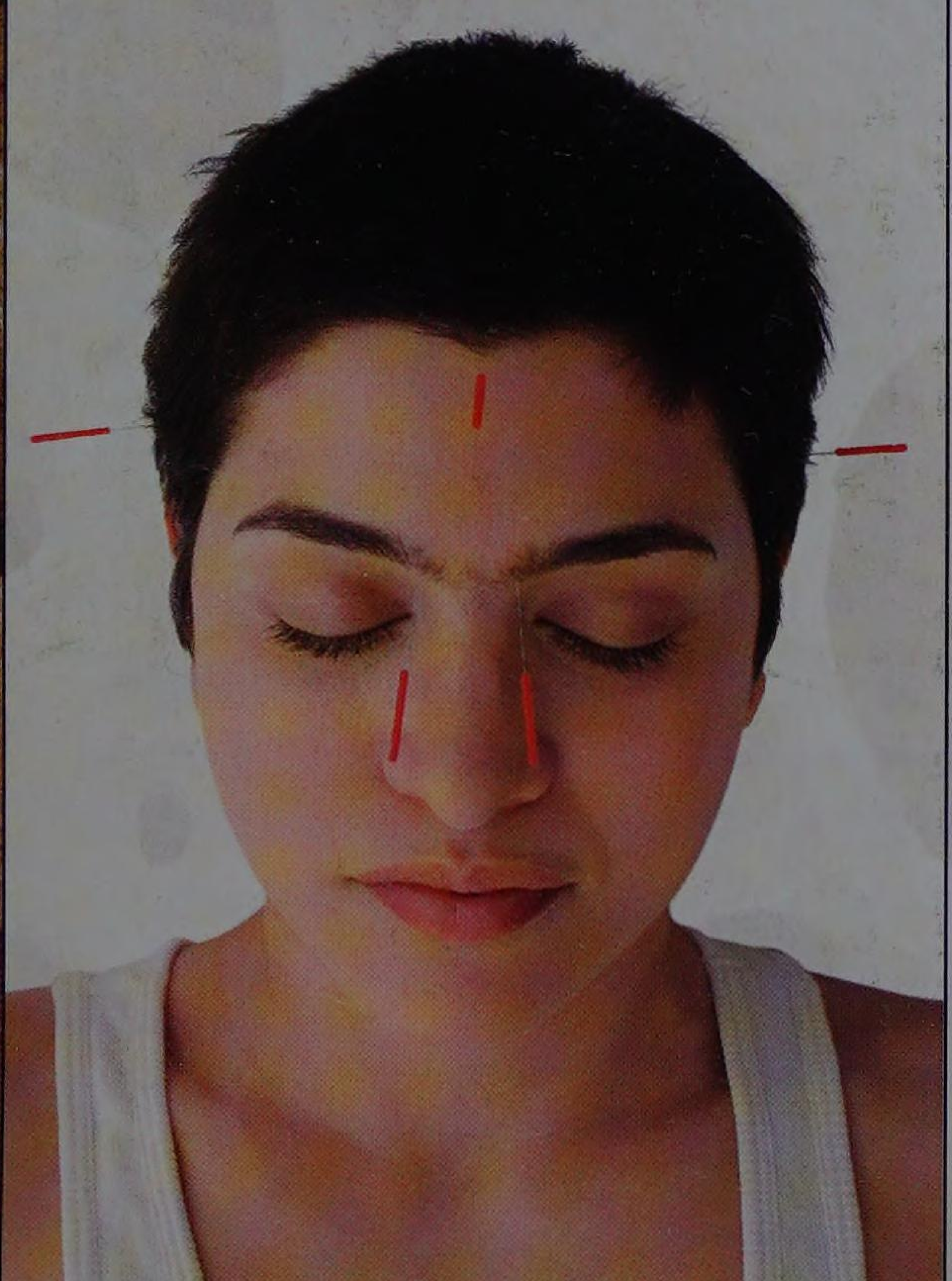
ANTIBODY A substance released by cells called lymphocytes, which marks an invading pathogen or germ for destruction.

ARTERY A blood vessel that carries blood from the heart towards the body tissues.

ATOM The smallest particle of an element, such as carbon or hydrogen, that can exist.

BACTERIA A type of microorganism. Some bacteria are pathogens (germs) that cause disease in humans.

BILE A fluid delivered from the liver to the intestine to aid digestion.



Acupuncture needles inserted into the skin to provide pain relief

BLOOD VESSEL A tube, such as an artery, vein, or capillary, that transports blood around the body.

CAPILLARY A microscopic blood vessel that links arteries to veins.

CARTILAGE A tough, flexible tissue that supports the nose, ears, and other body parts, and covers bones' ends in joints.

CELL One of the trillions of microscopic living units that make up a human body.

CHROMOSOME One of 46 packages of DNA found inside most body cells.

CHYME A soup-like liquid that is formed of part-digested food in the stomach and released into the small intestine.

DIAPHRAGM The dome-shaped muscle between the thorax and the abdomen.

DIGESTION The breakdown of the complex molecules in food into simple nutrients, such as sugars, which are absorbed into the bloodstream and used by cells.

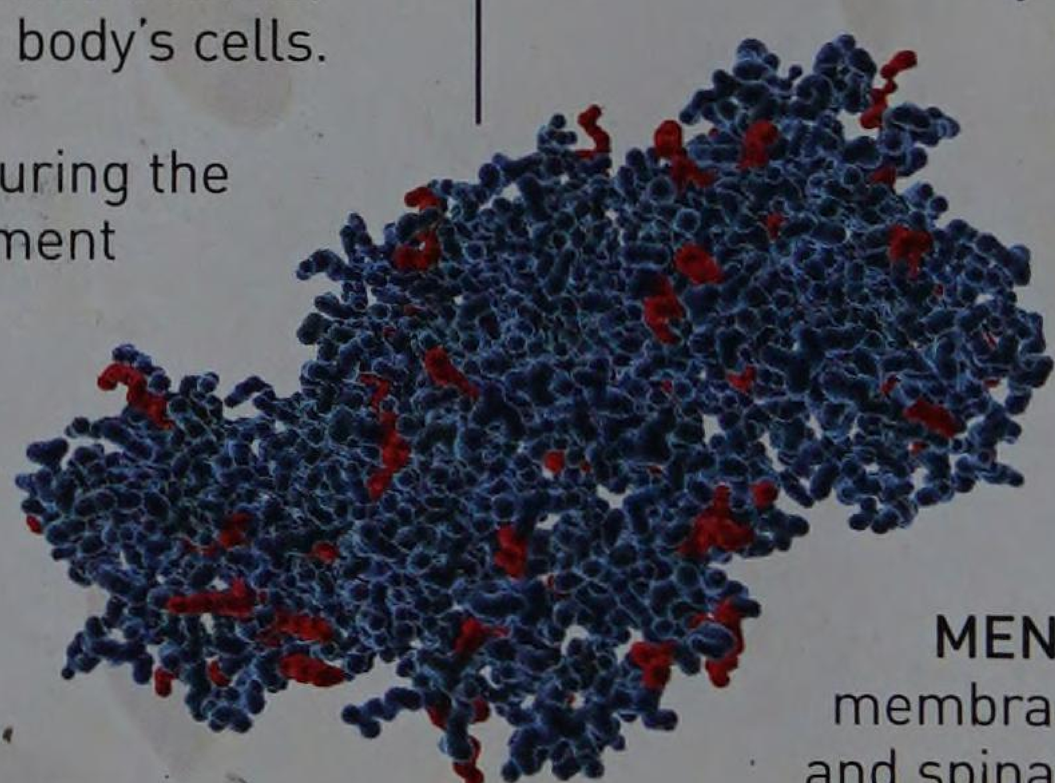
DISSECTION The careful cutting open of a dead body to study its internal structure.

DNA (DEOXYRIBONUCLEIC ACID) A molecule containing genes (instructions) for building and running the body's cells.

EMBRYO An unborn baby during the first eight weeks of development after fertilization.

ENDOCRINE GLAND A collection of cells, such as the thyroid gland, that release hormones into the bloodstream.

ENZYME A protein that acts as a biological catalyst to speed up the rate of chemical reactions inside and outside cells.



Model of an enzyme involved in digesting food

FAECES The semi-solid waste made up of undigested food, dead cells, and bacteria, removed from the body through the anus.

FERTILIZATION The fusion of a sperm and an egg to make a new human being.

FETUS A baby growing inside the uterus from its ninth week until its birth.

FOLLICLE A group of cells inside an ovary that surrounds and nurtures an egg. Also a pit in the skin from which a hair grows.

GAS EXCHANGE The movement of oxygen from the lungs into the bloodstream, and of carbon dioxide from the bloodstream into the lungs.

GENE One of 20,000–25,000 instructions contained within a cell's chromosomes that control its construction and operation.

GLAND A group of cells that create chemical substances, such as hormones or sweat, and release them into the body.

GLUCOSE A type of sugar that circulates in the blood and provides cells with their major source of energy.

HOMEOSTASIS The maintenance of stable conditions, such as temperature or amount of water or glucose, inside the body so that cells can work normally.

HORMONE A chemical messenger that is made by an endocrine gland and carried in the blood to its target tissue or organ.

IMMUNE SYSTEM A collection of cells in the circulatory and lymphatic systems that track and destroy pathogens (germs).

KERATIN The tough, waterproof protein in cells that make up the hair, nails, and upper epidermis of the skin.

LYMPH The fluid that flows through the lymphatic system from tissues to the blood.

MEMBRANE A thin layer of tissue that covers or lines an external or internal body surface. Also a cell's outer layer.

MENINGES The protective membranes that cover the brain and spinal cord.

MENSTRUAL CYCLE The sequence of body changes, repeated roughly every 28 days, that prepare a woman's reproductive system to receive a fertilized egg.

METABOLISM The chemical processes that take place in every cell in the body, resulting, for example, in the release of energy and growth.

MOLECULE A tiny particle that is made up of two or more linked atoms.

NEURON One of the billions of nerve cells that make up the nervous system.

Neurons carry electrical signals in the body's communication network

NUTRIENT A substance, such as glucose (sugar), needed in the diet to maintain normal body functioning and good health.

OLFACTORY To do with the sense of smell.

ORGAN A body part, such as the heart, that is made up of two or more types of tissue and carries out a particular function.

OSSIFICATION The formation of bone, replacing cartilage with bone tissue.

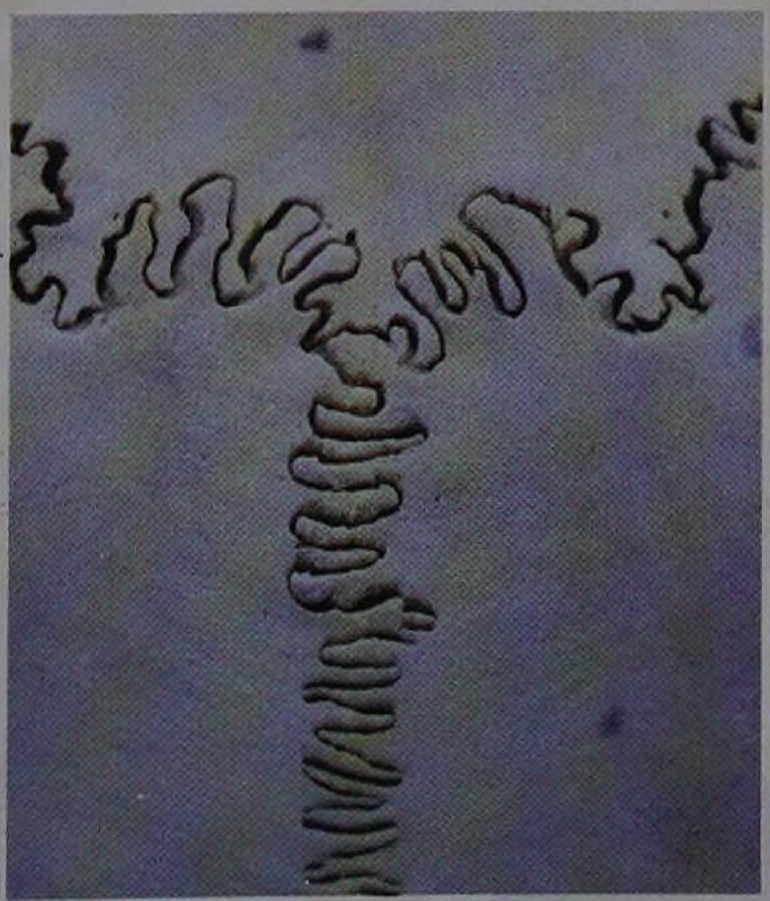
PATHOGEN A germ, a type of microorganism, such as a bacterium or virus, that causes disease in humans.

PHYSICIAN A doctor.

PHYSIOLOGY The study of the body's functions and processes – how it works.

PLACENTA The organ that delivers food and oxygen to a fetus from its mother. Half develops from the mother's body, and half is part of the fetus's body.

PREGNANCY The period of time between an embryo implanting in the uterus and a baby being born, usually 38–40 weeks.



Sutures, or jigsaw-like joints in the skull

PUBERTY The part of adolescence when a child's body changes into an adult's and the reproductive system starts to work.

SPERM Male sex cells, also called spermatozoa.

SPINAL CORD A column of nervous tissue inside the spine. It relays nerve signals between the brain and body.

SURGERY The treatment of disease or injury by direct intervention, often using surgical instruments to open the body.

SUTURE An immovable joint such as that between two skull bones.

SYNAPSE A junction between two neurons, where a nerve signal is passed from cell to cell. The neurons are very close at a synapse, but they do not touch.

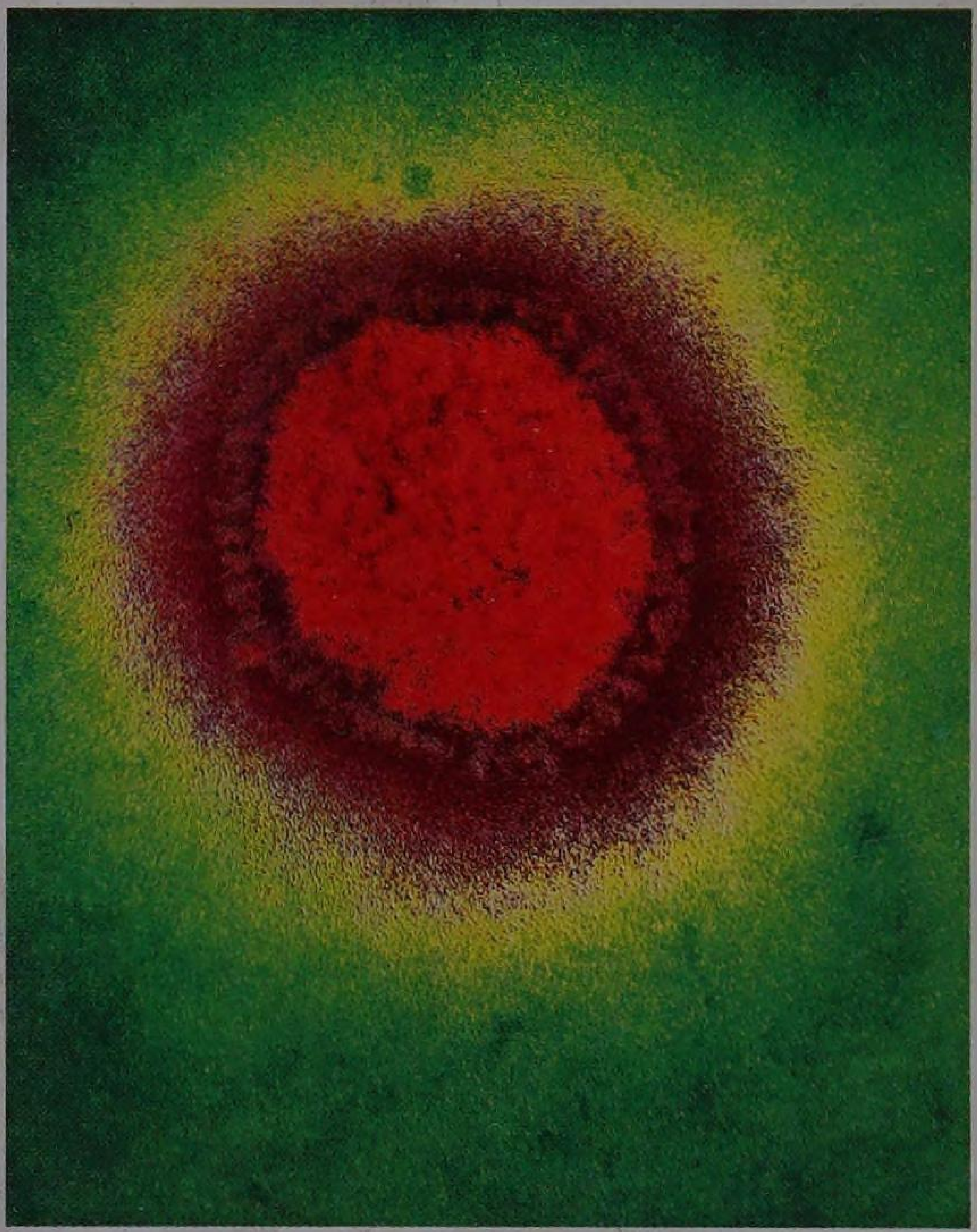
SYSTEM A collection of linked organs that work together to carry out a specific task or tasks. An example is the digestive system.

TISSUE An organized group of one type of cell, or similar types of cells, that works together to perform a particular function.

TORSO The central part of the body, also known as the trunk, made up of the thorax and abdomen.

UMBILICAL CORD The rope-like structure that connects a fetus to the placenta.

URINE A liquid produced by the kidneys that contains wastes, surplus water, and salts removed from the blood.



TEM of an influenza (flu) virus magnified 135,000 times

VEIN A blood vessel that carries blood from the body tissues towards the heart.

VIRUS A non-living pathogen that causes diseases, such as colds and measles, in humans.

X-RAY A form of radiation that reveals bones when projected through the body onto film.

Index

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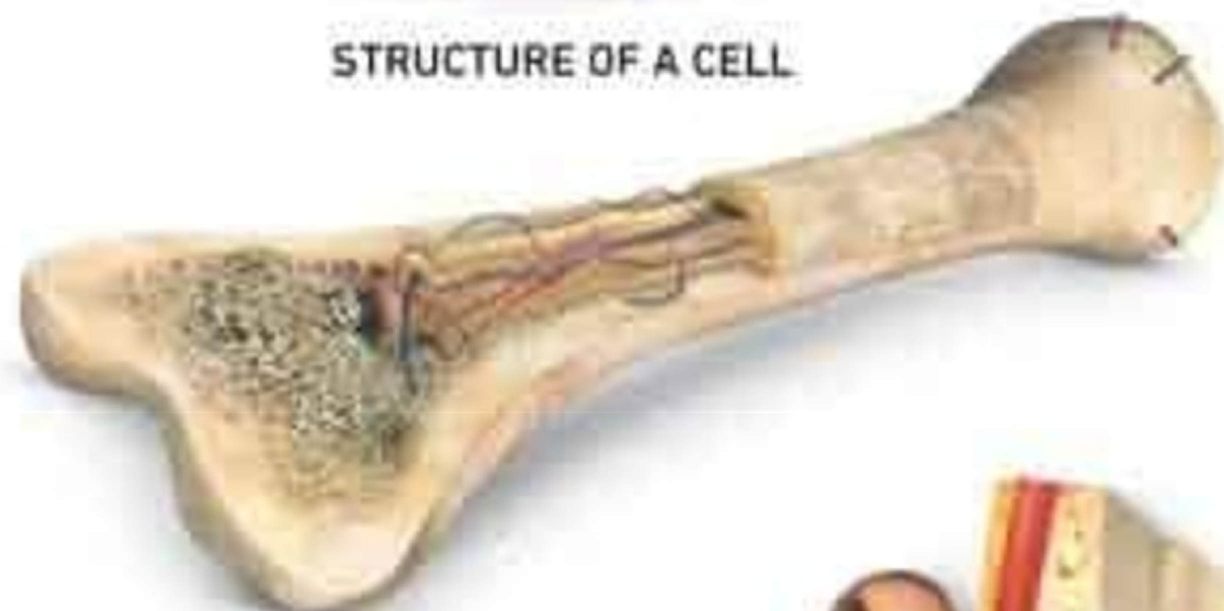

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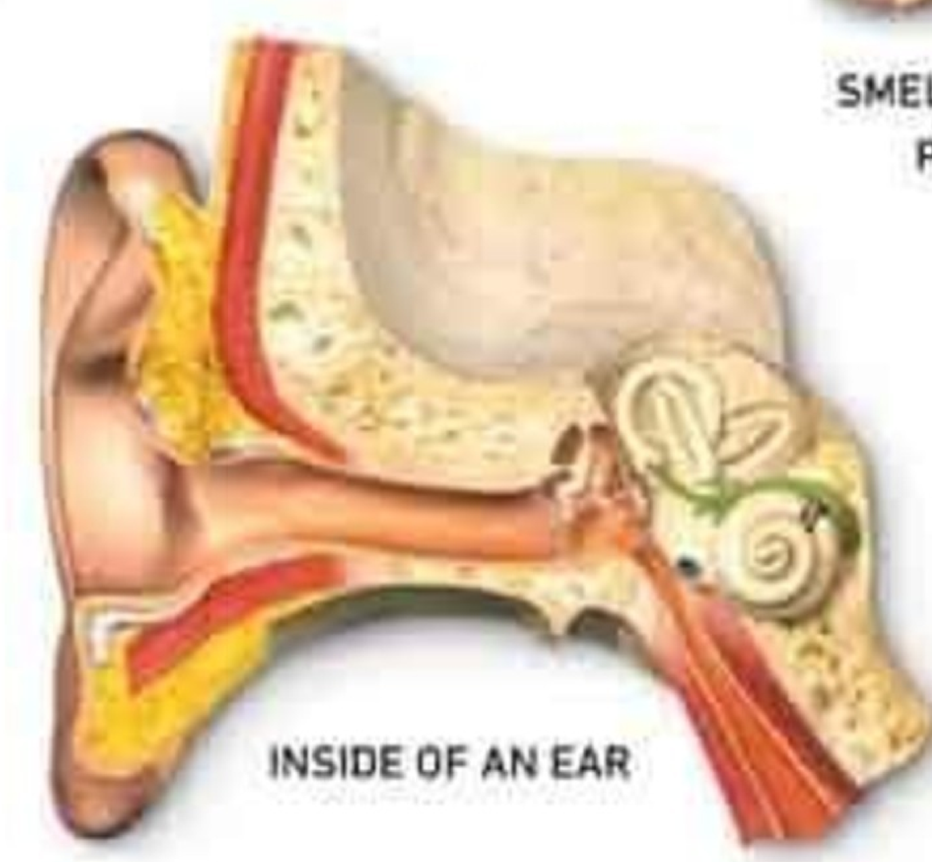

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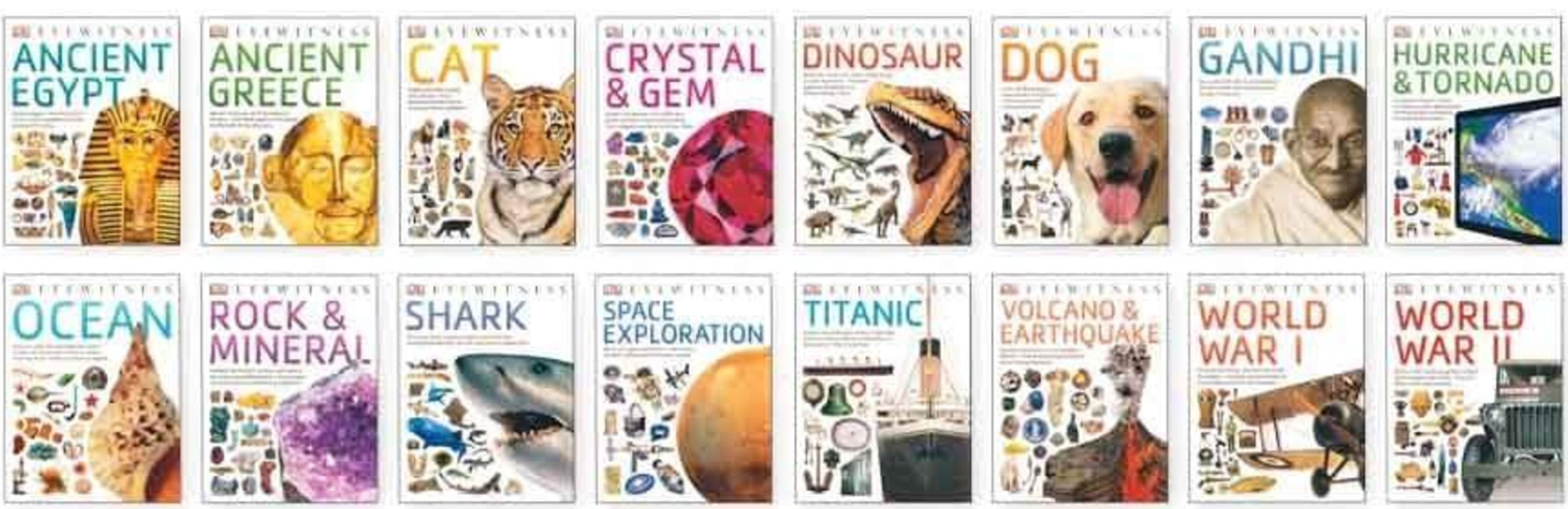

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